

DEVELOPMENT  
OF A  
BIAXIAL TEST FIXTURE

January 1980

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AEROSPACE STRUCTURES  
INFORMATION AND ANALYSIS CENTER

OPERATED FOR THE AIRFORCE FLIGHT DYNAMICS LABORATORY  
BY ANAMET LABORATORIES, INC.

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OF A  
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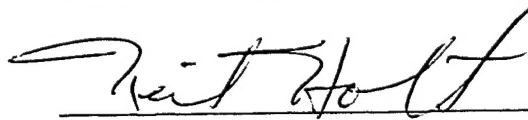
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January, 1980

This report describes the development, fabrication and testing of fixturing designed to determine the biaxial properties of materials. The fixturing was designed to be particularly compatible with composite materials, although it is not limited to use with those materials. As part of the work, a second fixture was built which applies only internal pressure to thin ring specimens.

The work was done by the Aerospace Structures Information and Analysis Center, which is operated for the Air Force Flight Dynamics Laboratory, by Anamet Laboratories, Inc., under Contract No. F33615-77-C-3046. The work was performed under ASIAC Problem No. 112.

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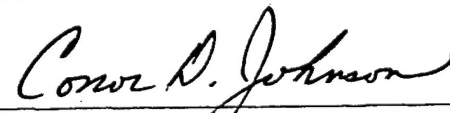
  
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## I. INTRODUCTION

The Aerospace Structures Information and Analysis Center has designed and fabricated a specimen load system for conducting biaxial material characterizations of composite materials. In particular, the system is useful for determining a major portion of the biaxial failure envelopes for composite materials. Portions of the triaxial failure surface where at least two of the principal stresses are negative may also be explored with the system. In addition, with proper control, the system may be used to evaluate the multiaxial fatigue properties of composites. Materials with high Poisson's ratios, which cannot usually be evaluated with ring burst tests, may be easily tested in the ASIAC system. Theoretical aspects of the system have been described in Anamet Laboratories, Inc. Report No. 277.502, "Technical Proposal for Test System for Conducting Biaxial Tests of Composite Laminates." Design of the test system is such that it is best used with any standard compression or universal testing machine with a minimum capacity of 100,000 lbs.

The test system, which is useful for examining quadrants II, III and IV of the biaxial stress plane, utilizes short cylindrical specimens. The specimens may be loaded with combinations of axial compression, internal pressure and external pressure. A unique feature of the test system is that end restraints are minimized by applying all loads through hydrostatic pressures. Hoop stresses are produced by applying internal or external pressures through the use of pressurized oil. Radial stresses may be produced by simultaneously applying internal and external pressures. Axial stress is induced through specimen interaction with a high pressure lubricant trapped between the specimen ends and parallel platens.

Because of the mechanism of loading, restraint to end dilation and twisting is governed by the viscous or plastic

shear strength of the lubricant. Lead foil, indium foil, polyethylene film and combination stacks of films and foils have been evaluated for use as the solid high pressure lubricant. The solid lubricant serves other functions in addition to minimizing restraint. For example, the foil compensates for slight irregularities and mismatch between platens and specimens. It also assists in the attainment of an oil-tight seal between the specimen ends and platens. Such a seal is necessary for the application of surface oil pressures.

This report describes the development of the system to date and some of the problems encountered. It also presents the results of biaxial testing of specially made and strain gaged composite specimens. The test results are quite encouraging, and they show that further refinement and use of the system is warranted.



## II. DESCRIPTION OF TEST SYSTEM

Principal components of the platen and pressure system are shown in Figure 1. A dimensioned drawing of the system is given in Figure 2. The small hollow cylinder acts as the lower platen. A step in the solid cylinder serves as the upper platen bearing surface. The upper platen is stepped to reduce the area perpendicular to the specimen axis. This reduces the axial load required to overcome the axial resultant of the oil pressure and allows a smaller testing machine to be used. The platens are made from through-hardened 4340 steel to minimize specimen damage to the platen surfaces. If damage or wear should occur, the through-hardening allows the platens to be reground without the necessity for repeating case hardening or heat treating.

Specimens compatible with the biaxial fixture are approximately 4 inch in diameter and less than 3 inches in length. Typical test specimens and foil gaskets are shown in Figure 3. The specimens are sandwiched between gaskets which bear against the two platens. Gasket performance was evaluated by crushing a series of Fiberglas epoxy specimens using various gasket combinations. During those tests, specimen hourglassing, or barreling, was monitored using dial gages. It was found that a laminate gasket consisting of 0.003 inch polyethylene sandwiched between 0.002 inch soft lead foil generally produced the least amount of hourglassing or barreling.

A photograph of the fixturing installed in an MTS Model 810, 110 kip, servohydraulic testing machine is given in Figure 4. In this figure, the specimen is about to be tested under axial compression. A self-aligning platen is secured to the load cell to eliminate eccentricity of the load axis. When internal pressure is applied, a splash guard and catch pan are incorporated in the system. For the application of external oil pressures, the heavy pressure collet is placed about the specimen,

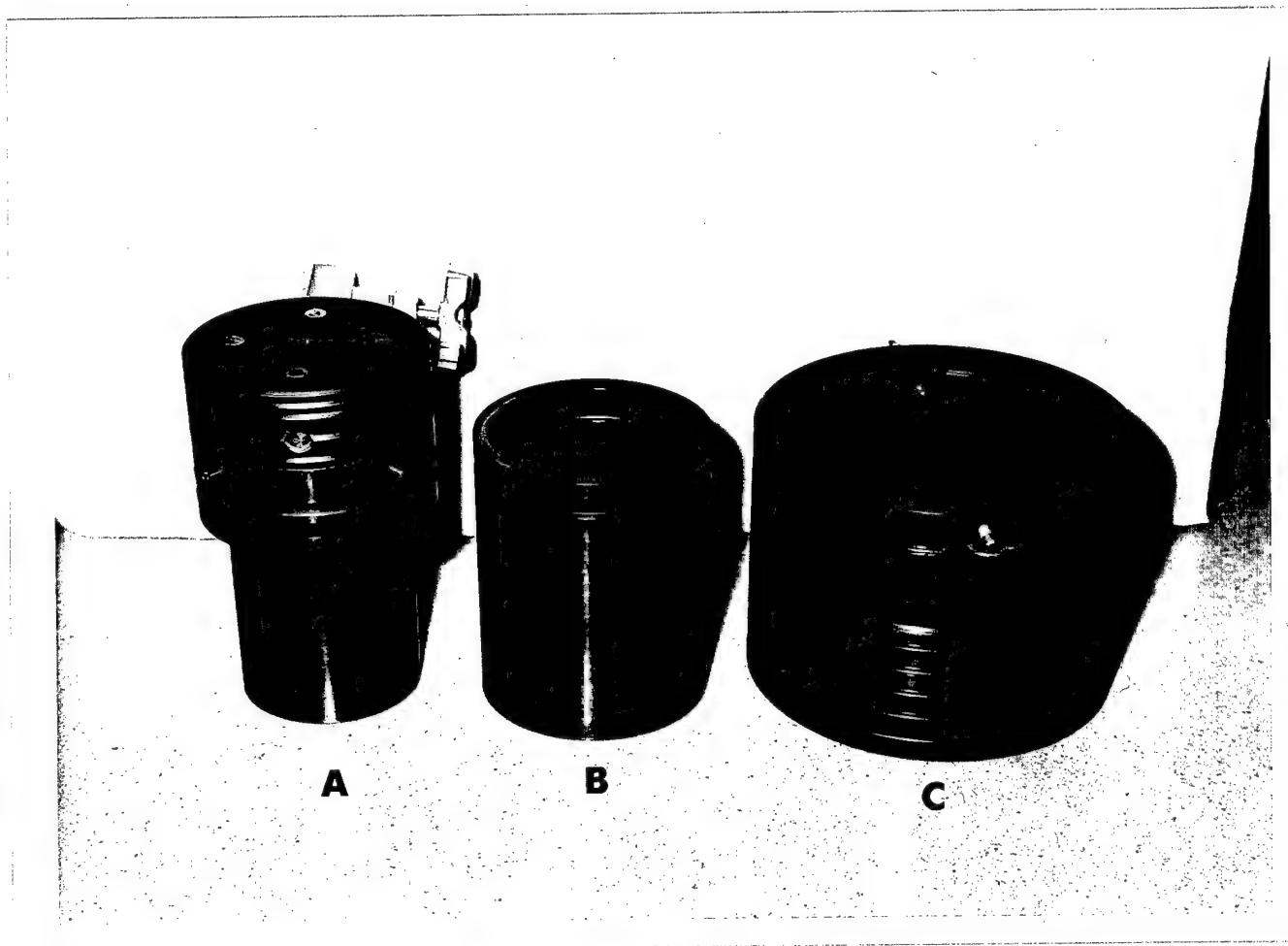
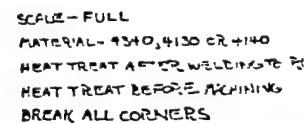
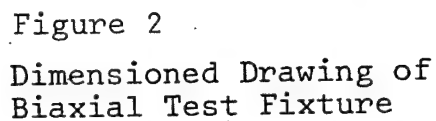


Figure 1    Principal Components of the  
Platen and Pressure System

- A - Upper Platen
- B - Lower Platen
- C - External Pressure Collet



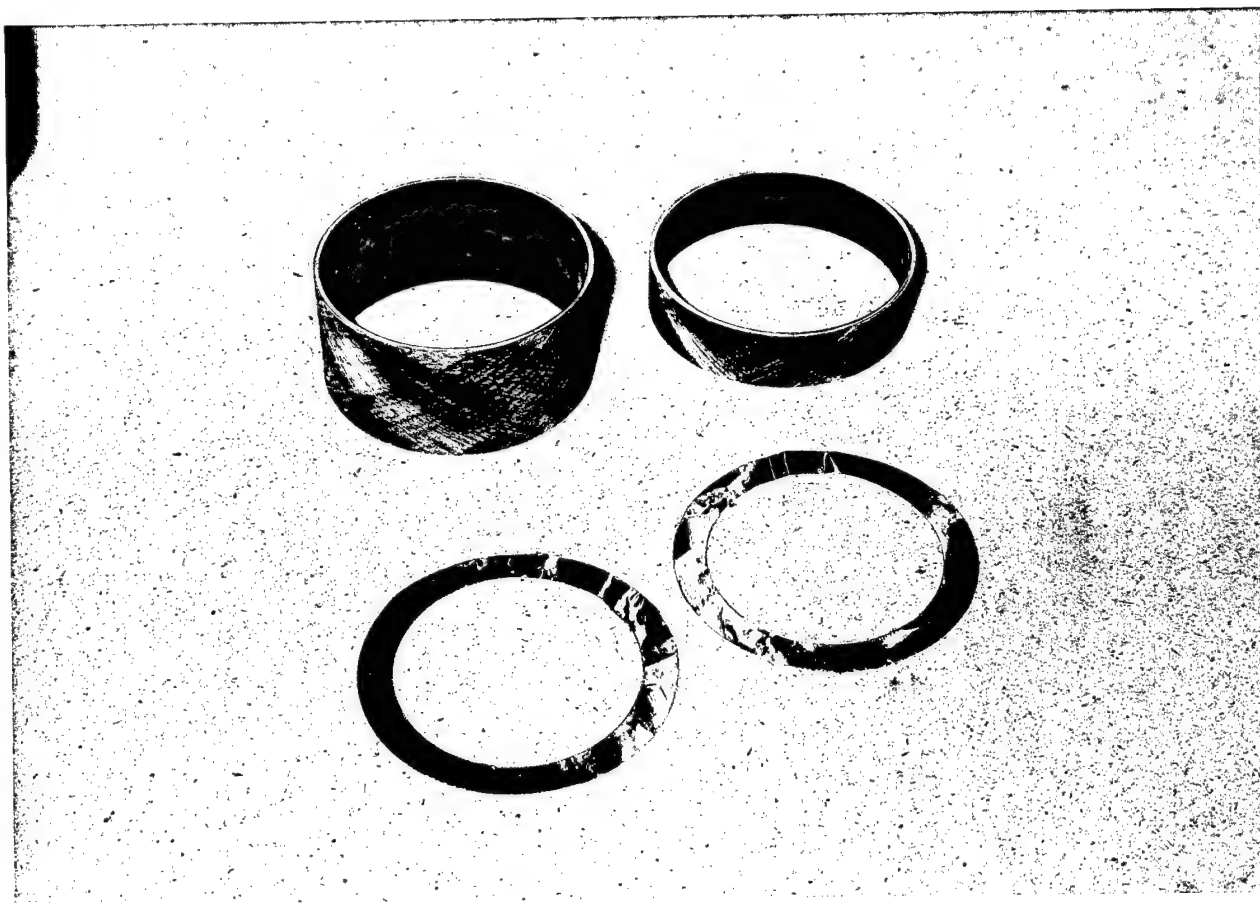


Figure 3    Typical Test Specimens and  
Foil Gaskets

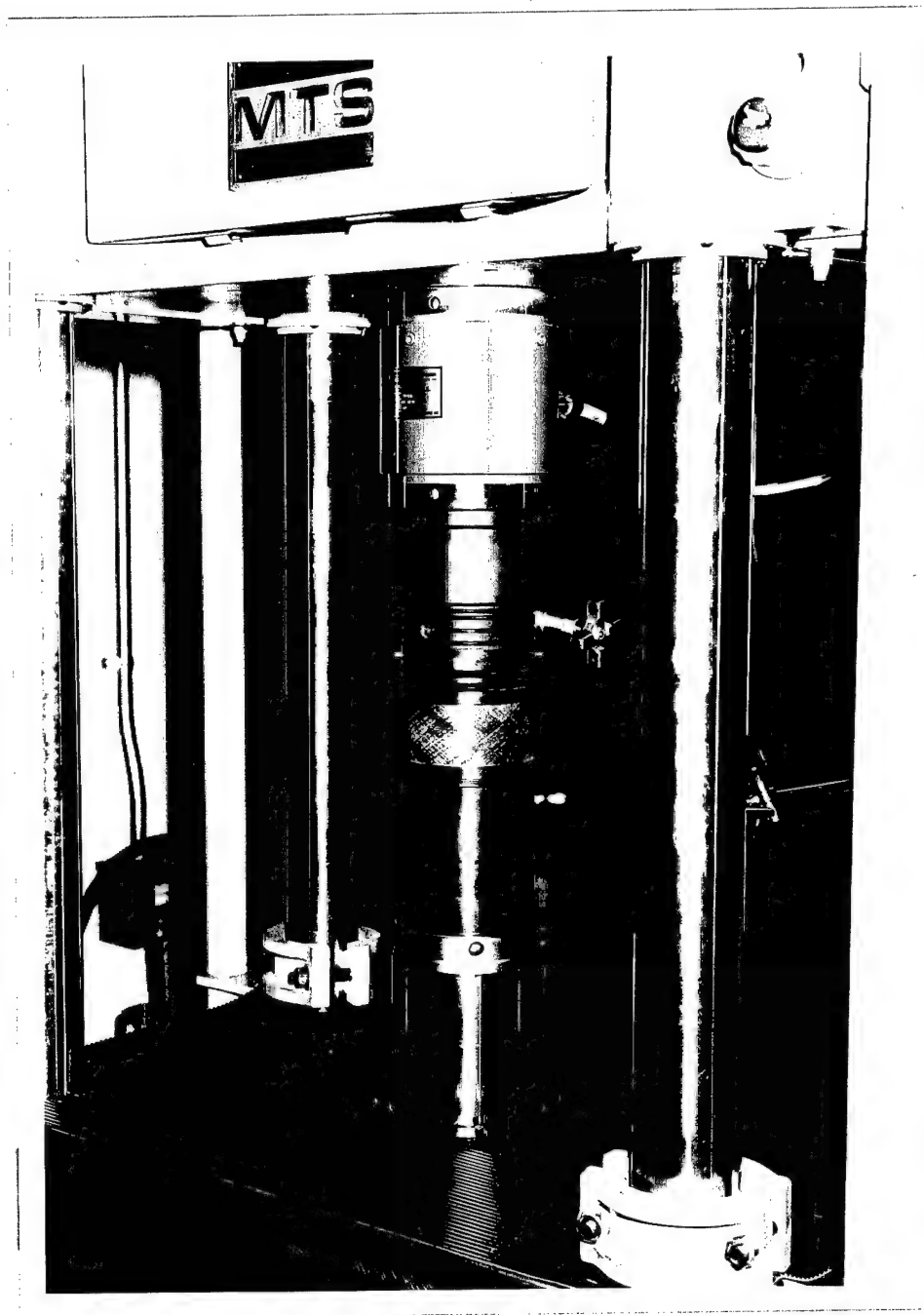


Figure 4     Fixture Installed in Testing Machine  
Prior to Axial Compression Test

as shown in Figure 5. The collet has been designed to withstand working pressures of 10,000 psi. In a few tests, an Enerpac 10,000 psi hydraulic power supply has been used to furnish the pressurized oil; however, hydraulic pressure for most of the tests was provided by an HIP, Inc. Model 87-6-5 manual pressure generator. Internal and external oil pressures were monitored with a standard pressure gage and a Datronic Model 502-3000G pressure transducer.

Many of the composite specimens tested in the fixture have been instrumented with resistive foil strain gages. Strain gage readings, as well as readings from the pressure transducer and MTS load cell, were taken using a Sun Systems ADACUS Data Processing and Readout System. This system contains an AD-I-SCE-10/32 Data Monitor with analog to digital converter, a DCP-10/P2/ADC-1 Display/Control Printer and two IM32/16 input multiplexers. Bridge completion, balancing and calibration are all internal to the Sun System. Internal calibrations are always checked with external shunt resistors. In the print mode, the ADACUS System scans at a rate of  $2\frac{1}{2}$  channels per second. As composite materials may be viscoelastic, the strain gage data should be taken as rapidly as possible. To speed up the system scan rate, the ADACUS System was modified to bypass the printer and send the data directly to the memory of an IMSAI 8080 microprocessor. This allowed the scan rate to be increased to  $12\frac{1}{2}$  channels per second. After completion of a test, the stored data was read into an ASR33 TTY, where punch tape and hardcopy records were made. Later, the punch tapes were read through the ASR33 and a file created in a PDP11/34. Loads corresponding to strain values were found through linear interpolation with time. A specially written program in the PDP11/34 allowed plots to be made of strains vs. stresses (see Appendix A). The plots were made on a TEKTRONIX Model 4631 hardcopy unit.

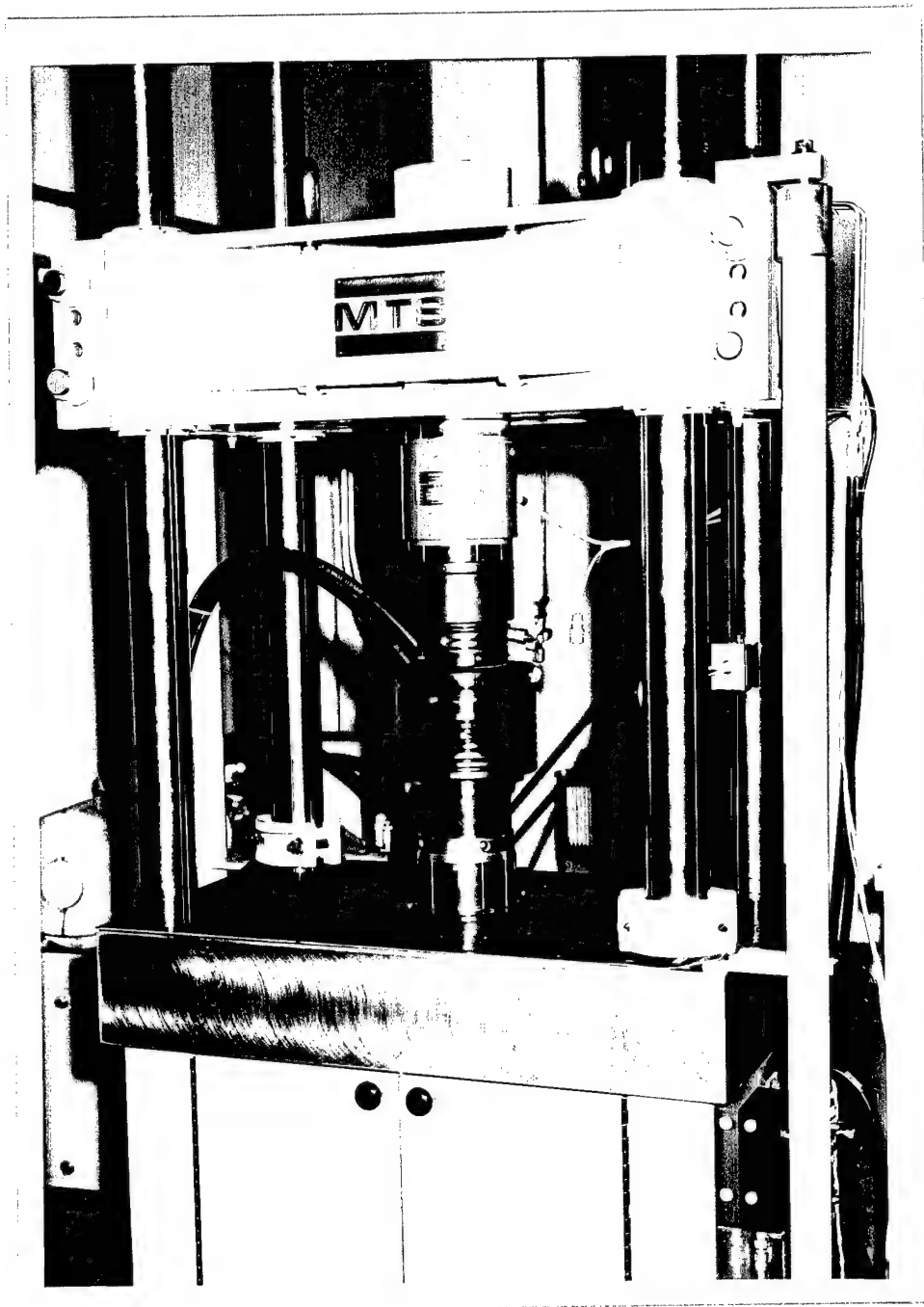


Figure 5    Fixture Installed in Testing Machine Prior  
to External Pressure and Axial Compression  
Test

It was discovered early in the program that the foil gaskets by themselves could not adequately contain the pressurized oil. To overcome this problem, and to prevent the oil from contacting the specimens, rubber gaskets were designed and incorporated into the system. The gaskets were molded from butyl rubber with a Shore A hardness of 60. They were precision molded tubes with wall thicknesses of 0.125 inches and heights 0.025 inches higher than the composite specimens. The rubber gasket diameters were such that some gaskets could be slipped inside the specimens and others could be slipped outside the specimens. Small openings were cut in the rubber gaskets to allow penetration of strain gage leads. After the leads were passed through the openings, RTV rubber was applied as a sealant. Small connector plugs were epoxy potted inside the pressure collet and in a groove machined in the center plug. Strain gage leads were terminated with plugs mating with the potted plugs. With this arrangement, hydraulic oil pressures could be applied to the specimens, and at the same time, strain gage readings taken.



### III. DESCRIPTION OF SPECIMENS

In the initial development of the system, numerous specimens were tested to evaluate various gasket combinations and seal systems. Those tests were largely qualitative, and data was not recorded. Due to availability and attractive cost, the preliminary test specimens were made from Bondstrand 2000 Fiberglas-reinforced epoxy resin pipe. Details of the ply layup were unknown; however, it appeared to be a wound  $\pm 45^\circ$  structure. The Fiberglas epoxy specimens had an outside diameter of 4.375 in., a wall thickness of typically 0.100 in. and heights of either 1.000 in. or 2.000 in.

After seal and gasket problems were solved, a number of uninstrumented graphite-epoxy specimens were tested under internal pressure and axial load. Those specimens had outside diameters of 4.000 in., wall thicknesses of 0.043 in. and heights of either 1.000 in. or 2.000 in. Localized buckling problems with the first two of these specimens suggested the specimen ends were either not flat or not parallel. Careful measurements of the remaining specimens disclosed variations in height of as much as  $\pm 0.003$  inches. The specimen ends were then ground flat and parallel to within 0.0005 in. With this change, the localized buckling problems ceased. The purpose of the preliminary graphite-epoxy tests was to use dial gages to semi-quantitatively evaluate system performance with relatively thin walled high strength materials.

As the preliminary graphite-epoxy tests yielded promising results, a series of tests were performed on carefully made strain gaged specimens. The specimens were graphite-epoxy, and measured 4.000 inches O.D., were 1.000 inches high and had a wall thickness of 0.043 inches. The ends were ground flat and parallel to within 0.0005 inches. Four specimens had a  $[0^\circ/\pm 45^\circ/90^\circ]_s$  ply layup. All specimens were strain gaged, as shown in Figure 6. The instrumented specimens were provided by AFFDL.

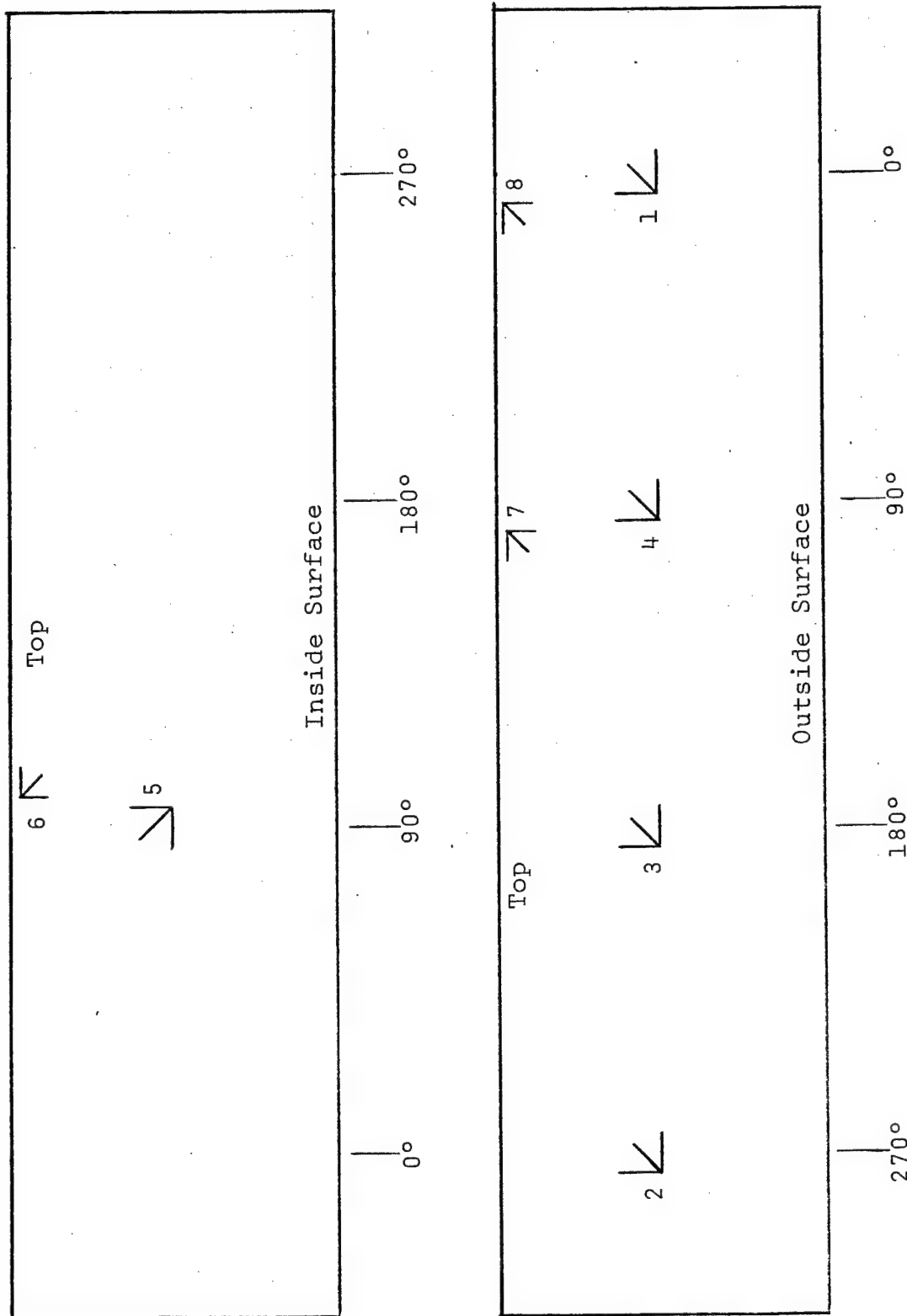


Figure 6 Unrolled view of specimen showing relative rosette locations and identifications. Rosettes 6, 7 & 8 are stacked rosettes with 0.062" gage lengths. The remaining rosettes are standard rosettes with 0.125" gage lengths.

#### IV. TEST RESULTS

Tests performed on the seven strain gaged specimens are summarized in Table 1.

TABLE 1  
SUMMARY OF TESTS

<u>Test No.</u>	<u>Specimen Type</u>	<u>Loading</u>	<u>Notes</u>
1	$\pm 45^\circ$	Axial only	
2	$0^\circ/\pm 45^\circ/90^\circ$	Internal pressure	200 lb. axial pre-load
3	$\pm 45^\circ$	Internal pressure	Constant 100 lb. axial load
4-A	$\pm 45^\circ$	Axial only	Same specimen, partial compressions
4-B	$\pm 45^\circ$	Axial only	Same specimen, partial compressions
4-C	$\pm 45^\circ$	Axial only	Same specimen, partial compressions
5	$\pm 45^\circ$	External pressure	Same specimen as used in 4-A,B,C
6	$0^\circ/\pm 45^\circ/90^\circ$	Internal pressure and axial load	Internal pressure equals axial load, pure shear condition
7	$0^\circ/\pm 45^\circ/90^\circ$	External pressure and axial load	Hoop stress equal to axial stress
8	$0^\circ/\pm 45^\circ/90^\circ$	External pressure	Edge damaged - not tested

For each of the tests performed, stress-strain plots were created from strain gage, load cell and pressure transducer outputs. The stress-strain plots for each test are summarized in Table 2.

TABLE 2  
SUMMARY OF PLOTS

<u>Test No.</u>	<u>Description</u>	<u>Rosette Nos.</u>	<u>Figure No.</u>
1	Axial strain vs. axial stress	1,2,3,4	7
	Axial strain vs. axial stress	4,5	8
	Axial strain vs. axial stress	7,8	9
	Hoop strain vs. axial stress	2,3,4	11
	Hoop strain vs. axial stress	4,5	12
	Hoop strain vs. axial stress	6,7,8	13
	Max. shear strain vs. axial stress	2,3,4	14
	Max. shear strain vs. axial stress	4,5	15
	Max. shear strain vs. axial stress	6,7,8	16
2	Axial strain vs. hoop stress	1,2,3,4	17
	Axial strain vs. hoop stress	4,5	20
	Axial strain vs. hoop stress	6,7,8	23
	Hoop strain vs. hoop stress	1,2,3,4	18
	Hoop strain vs. hoop stress	4,5	21
	Hoop strain vs. hoop stress	6,7,8	24
	Max. shear strain vs. hoop stress	1,2,3,4	19
	Max. shear strain vs. hoop stress	4,5	22
	Max. shear strain vs. hoop stress	7,8	25
3	Axial strain vs. hoop stress	1,2,3,4	27
	Axial strain vs. hoop stress	4,5	30
	Axial strain vs. hoop stress	6,7,8	33
	Hoop strain vs. axial stress	1,2,3,4	28
	Hoop strain vs. axial stress	4,5	31
	Hoop strain vs. axial stress	6,7,8	34
	Max. shear strain vs. hoop stress	1,2,3,4	29
	Max. shear strain vs. hoop stress	4,5	32
	Max. shear strain vs. hoop stress	6,7,8	35
4-A	Axial strain vs. axial stress	1,2,3,4	37
	Axial strain vs. axial stress	4,5	40
	Axial strain vs. axial stress	6,7,8	43
	Hoop strain vs. axial stress	1,2,3,4	38
	Hoop strain vs. axial stress	4,5	41
	Hoop strain vs. axial stress	6,7,8	44
	Max. shear strain vs. axial stress	1,2,3,4	39
	Max. shear strain vs. axial stress	4,5	42
	Max. shear strain vs. axial stress	6,7,8	45

TABLE 2  
(Continued)

<u>Test No.</u>	<u>Description</u>	<u>Rosette Nos.</u>	<u>Figure No.</u>
4-B	Axial strain vs. axial stress	1,2,3,4	46
	Axial strain vs. axial stress	4,5	49
	Axial strain vs. axial stress	6,7,8	52
	Hoop strain vs. axial stress	1,4	47
	Hoop strain vs. axial stress	4,5	50
	Hoop strain vs. axial stress	6,7,8	53
	Max. shear strain vs. axial stress	1,4	48
	Max. shear strain vs. axial stress	4,5	51
	Max. shear strain vs. axial stress	6,7,8	54
4-C	Axial strain vs. axial stress	1,2,3,4	55
	Axial strain vs. axial stress	4,5	58
	Axial strain vs. axial stress	6,7,8	61
	Hoop strain vs. axial stress	1,2,3,4	56
	Hoop strain vs. axial stress	4,5	59
	Hoop strain vs. axial stress	6,7,8	62
	Max. shear strain vs. axial stress	1,2,3,4	57
	Max. shear strain vs. axial stress	4,5	60
	Max. shear strain vs. axial stress	6,7,8	63
5	Axial strain vs. hoop stress	5,6	68
	Hoop strain vs. hoop stress	5,6	69
	Max. shear strain vs. hoop stress	5,6	70
6	Axial strain vs. axial stress	1,2,3	73
	Axial strain vs. axial stress	6,7,8	74
	Hoop strain vs. hoop stress	1,2,3,4	75
	Hoop strain vs. hoop stress	4,5	76
	Hoop strain vs. hoop stress	7,8	77
7	Axial strain vs. axial stress	1,2,4	80
	Axial strain vs. axial stress	4,5	82
	Axial strain vs. axial stress	7,8	83
	Hoop strain vs. hoop stress	1,2,3,4	85
	Hoop strain vs. hoop stress	7,8	86
	Max. shear strain vs. axial stress	1,2	81
	Max. shear strain vs. axial stress	7,8	84

Only axial load was applied to the specimen in Test 1. The specimen layup was  $\pm 45^\circ$ . Figure 7 is a comparison of the axial strains vs. axial stress for the four gages located at the center of the specimen on the outside surface. The axial strain gage elements were not in close agreement, indicating either non-uniformity of load or local variations in specimen compliance. The specimen began to buckle when a compressive axial stress of approximately 19,000 psi was reached. This is shown by the curving back of the axial stress in this plot. Figure 8 is a comparison of the axial strains vs. axial stress for the two gages located at the center of the specimen but on opposite surfaces. The output from these gages show that no bending, and thus no buckling, was occurring at this position. Figure 9 is a comparison plot of axial strains vs. axial stress for the two gages located at the top of the specimen but on opposite surfaces. These figures show that the output from the gages at Points 1, 4, 5, 6, 7 and 8 compare fairly well, but do not compare with the output from gages at Points 2 and 3. Figure 10 is a photograph of this specimen after testing. This figure shows that the buckles occurred on the end opposite from gages at Points 6, 7 and 8. Figure 11 is a comparison plot of hoop strains vs. axial stress for three gages located at the center of the specimen on the outside surface. The hoop strain component for the strain rosette at Point 1 did not produce a signal. The shape of these curves matched the corresponding curves shown in Figure 7. Figures 12 and 13 are the comparison plots of hoop strains vs. axial stress for the gage locations corresponding to those of Figures 8 and 9, respectively. Again, the shapes of the curves are in agreement with the corresponding axial strain curves. Figures 14, 15 and 16 are comparison plots of the maximum shear strain vs. axial load for the gage locations presented in Figures 7, 8 and 9, respectively.

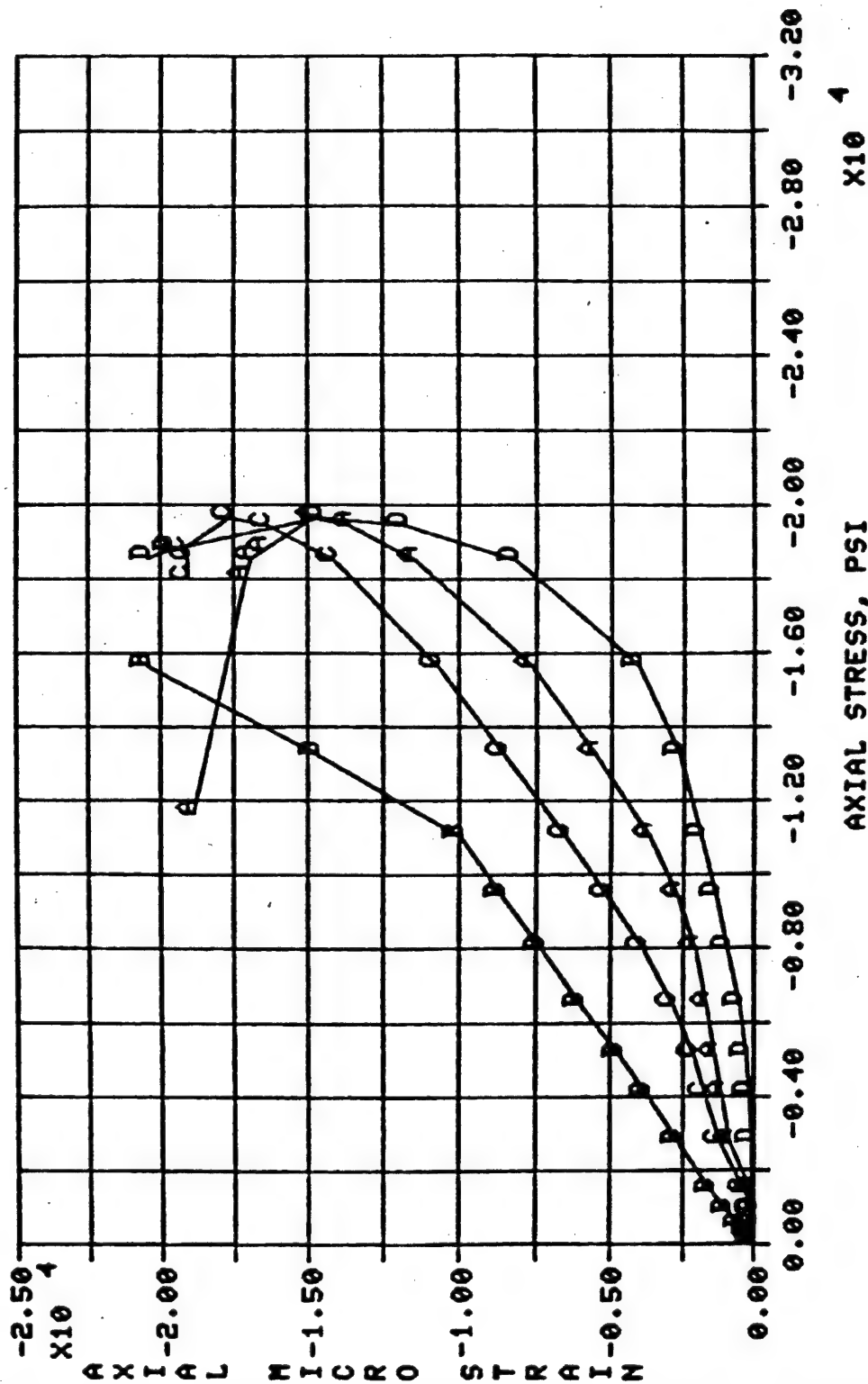


Figure 7 Test 1. Layup +45° Axial Load Only  
Axial Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

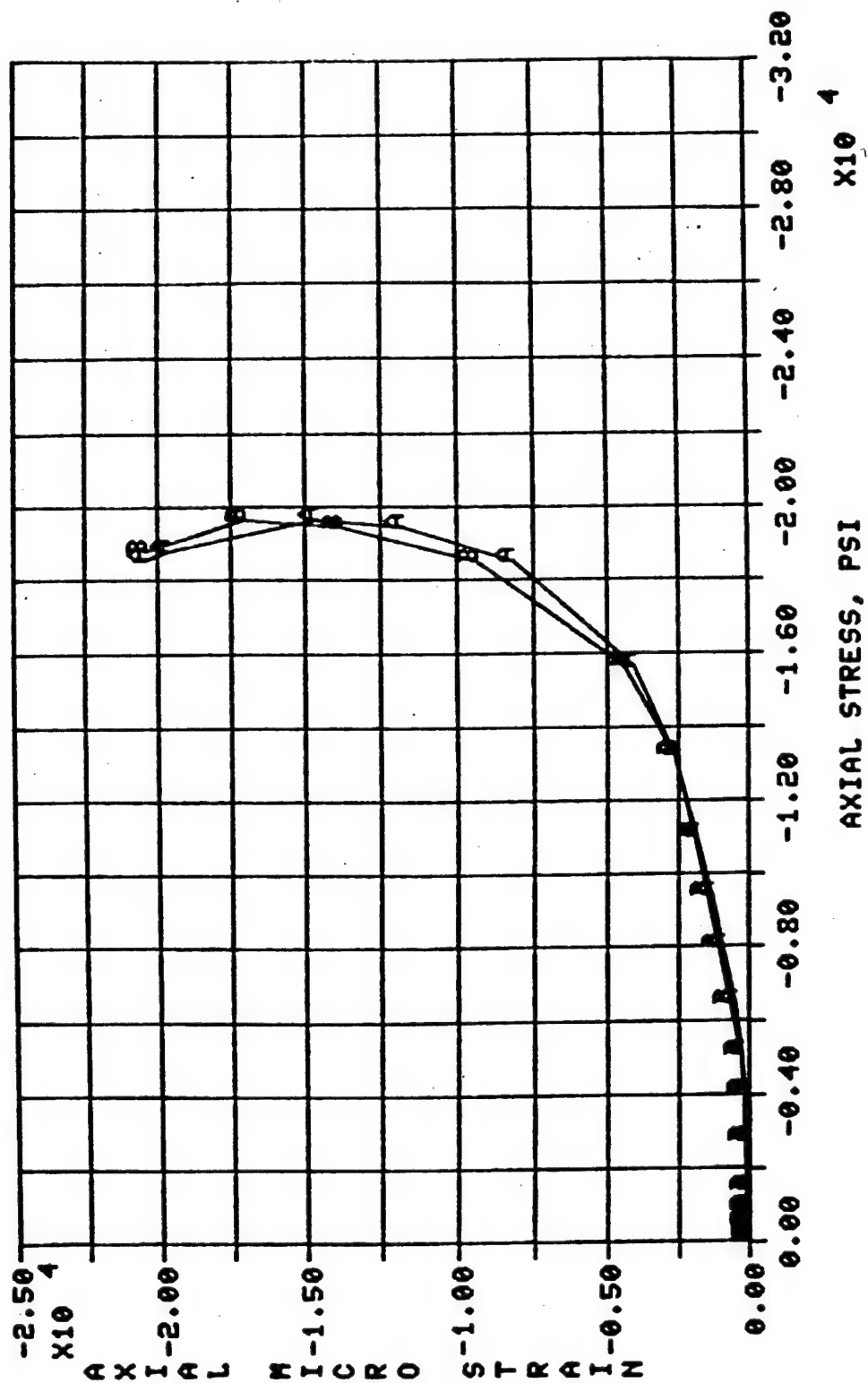


Figure 8 Test 1. Layup  $\pm 45^\circ$  Axial Load Only  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)



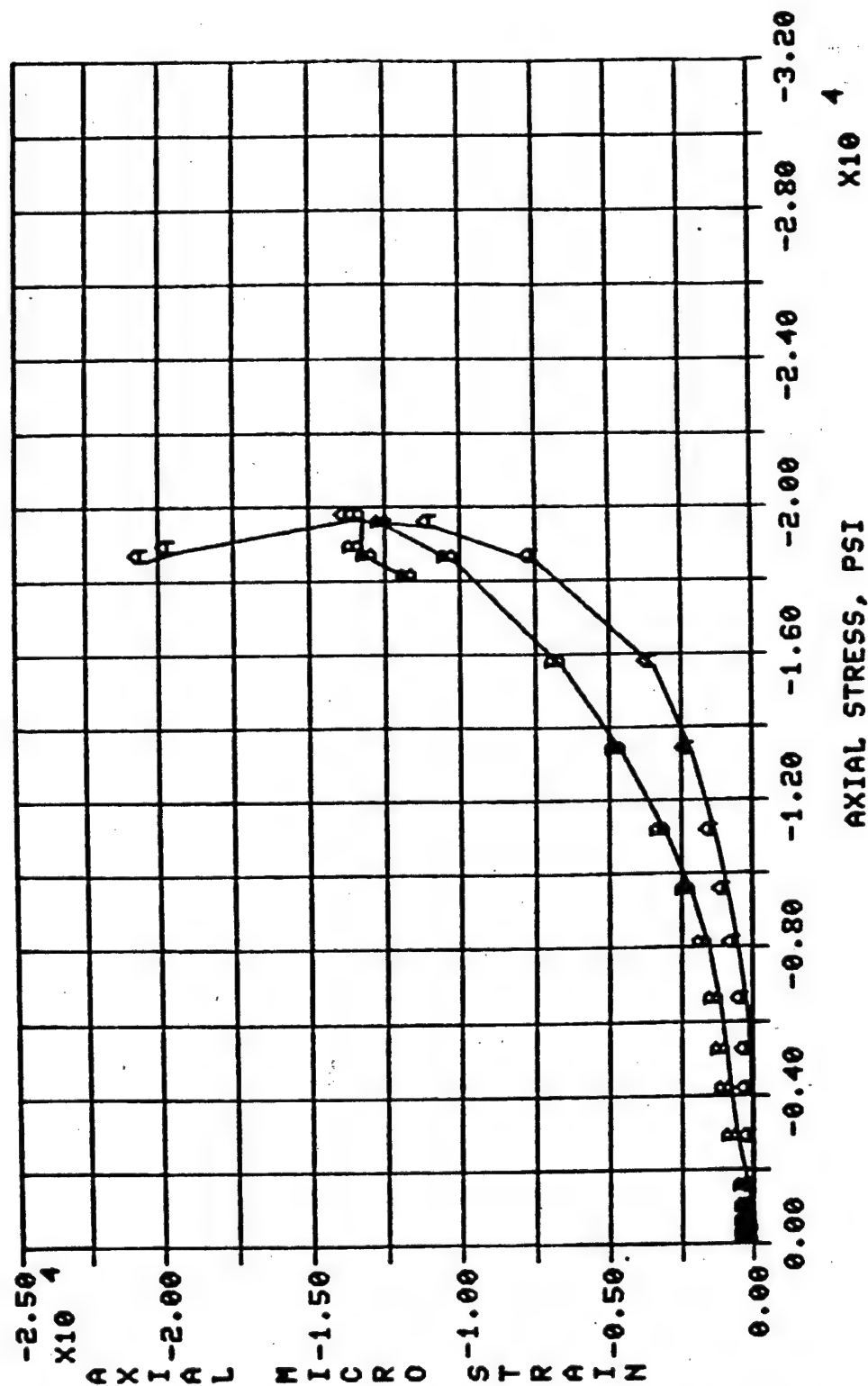


Figure 9 Test 1. Layup  $\pm 45^\circ$  Axial Load Only  
Axial Response, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8

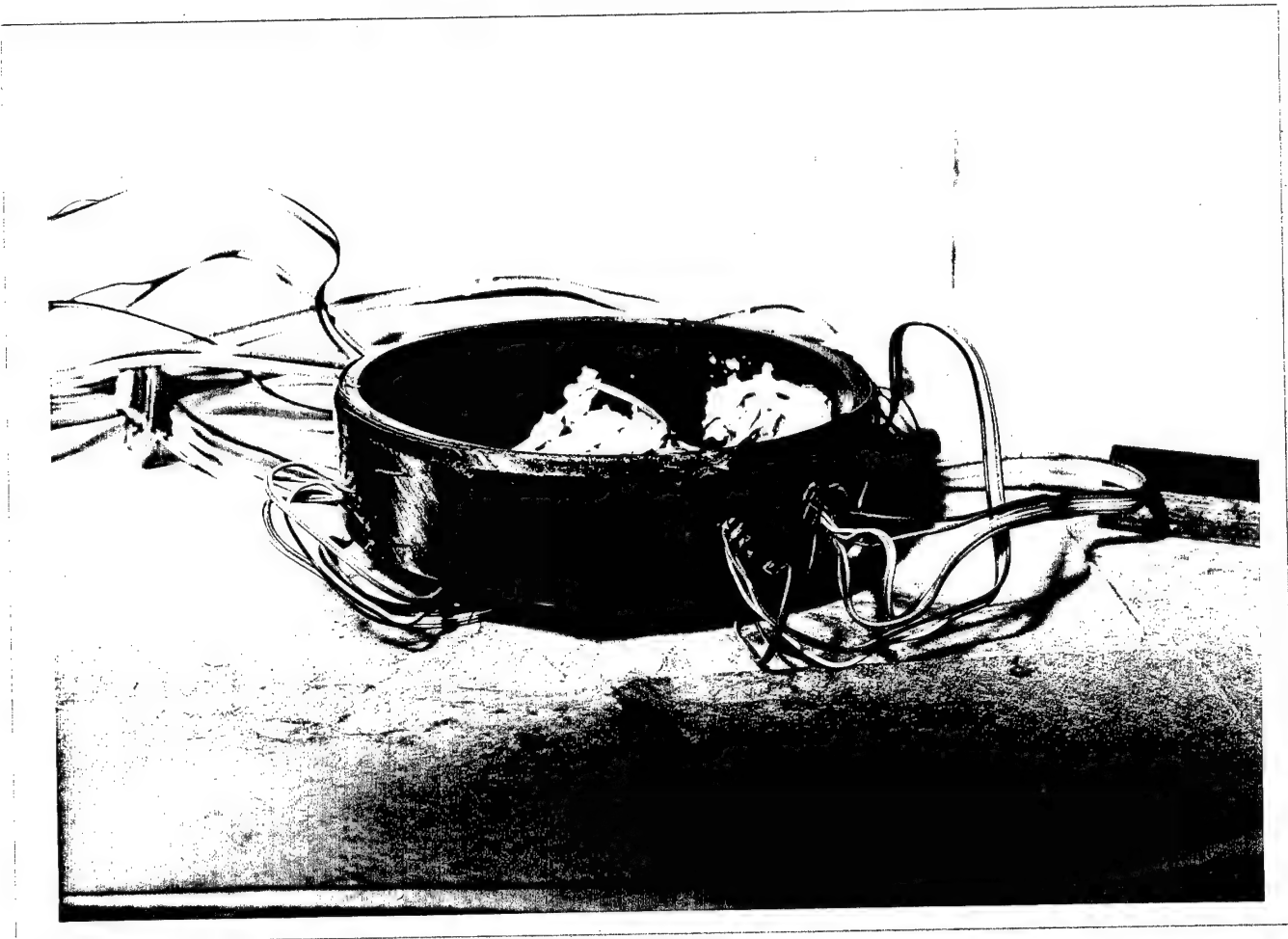


Figure 10    Test Specimen No. 1 After  
Crushing by Axial Load. Ply  
Layup is  $\pm 45^\circ$ .

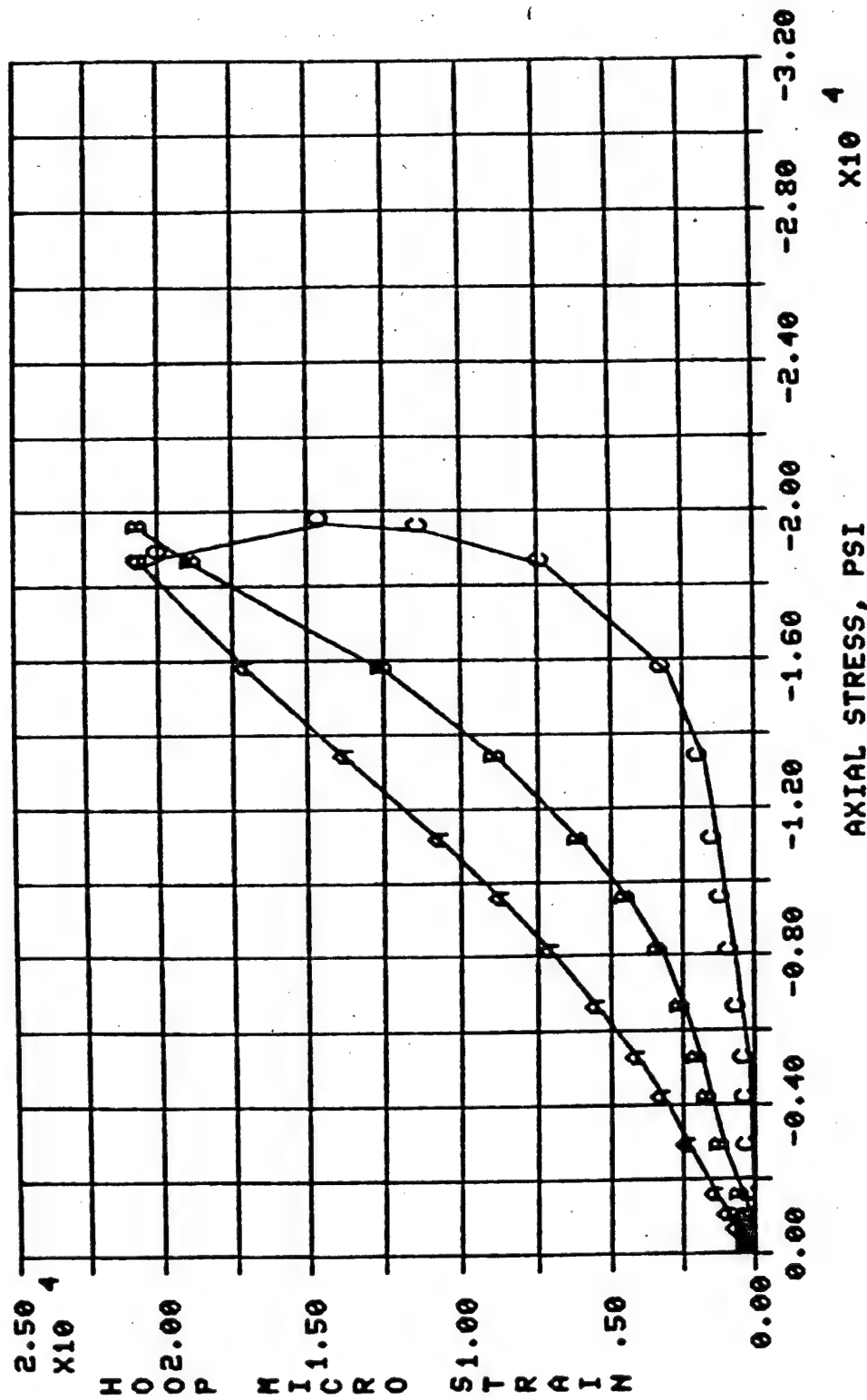


Figure 11 Test 1. Layup  $\pm 45^\circ$ , Axial Load Only  
Hoop Response, Outside Rosettes  
A - Rosette No. 2  
B - Rosette No. 3  
C - Rosette No. 4

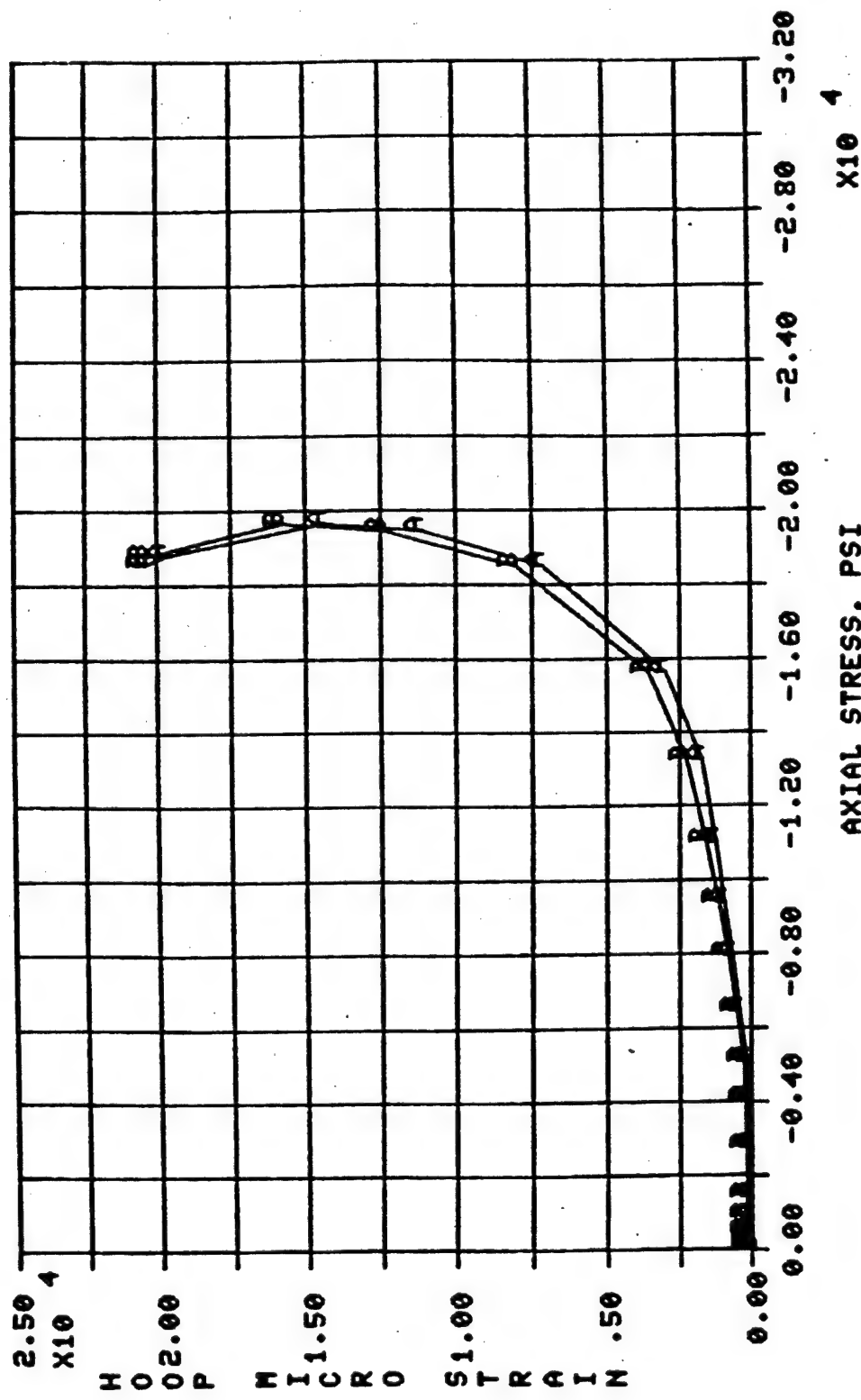


Figure 12 Test 1. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

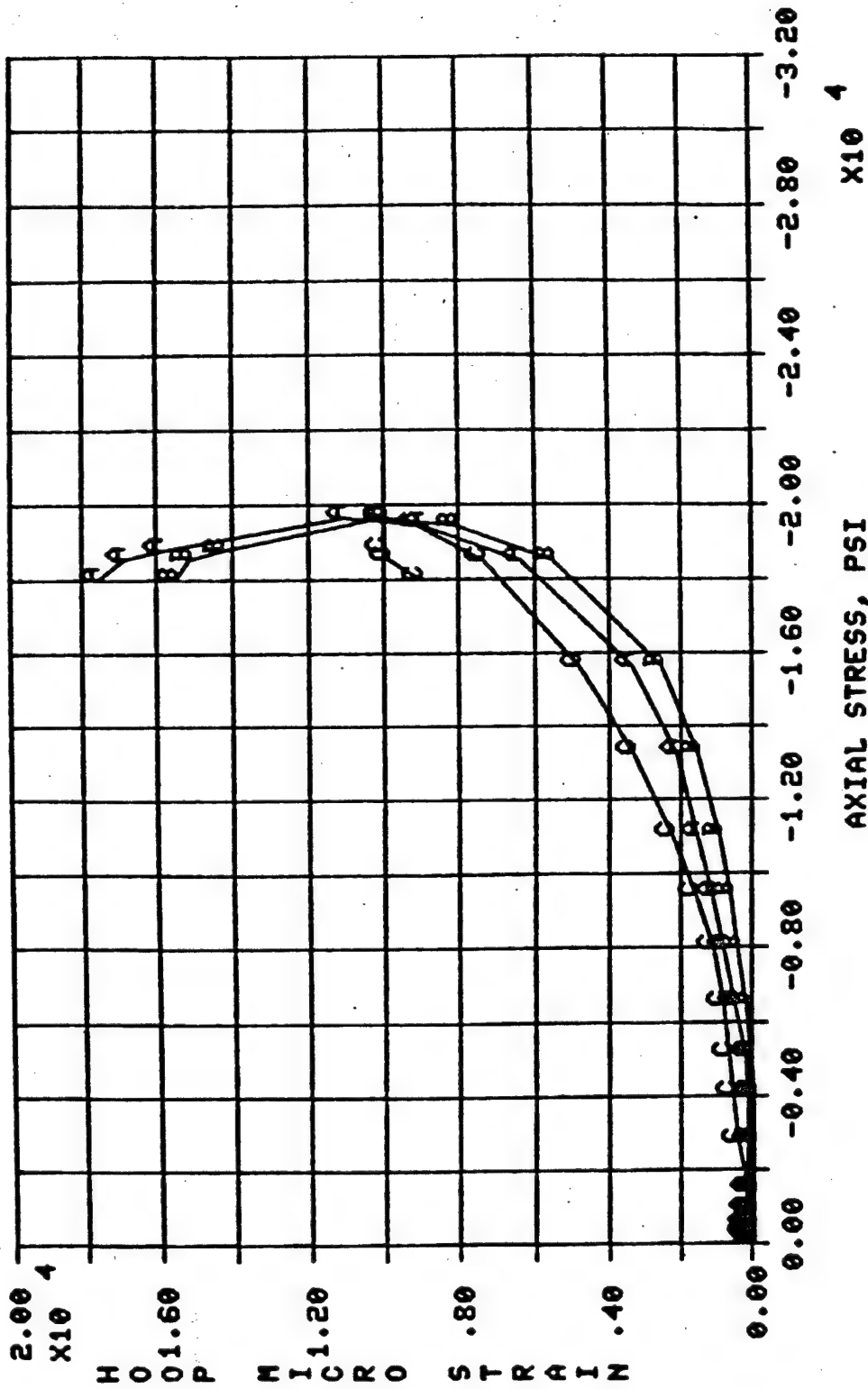
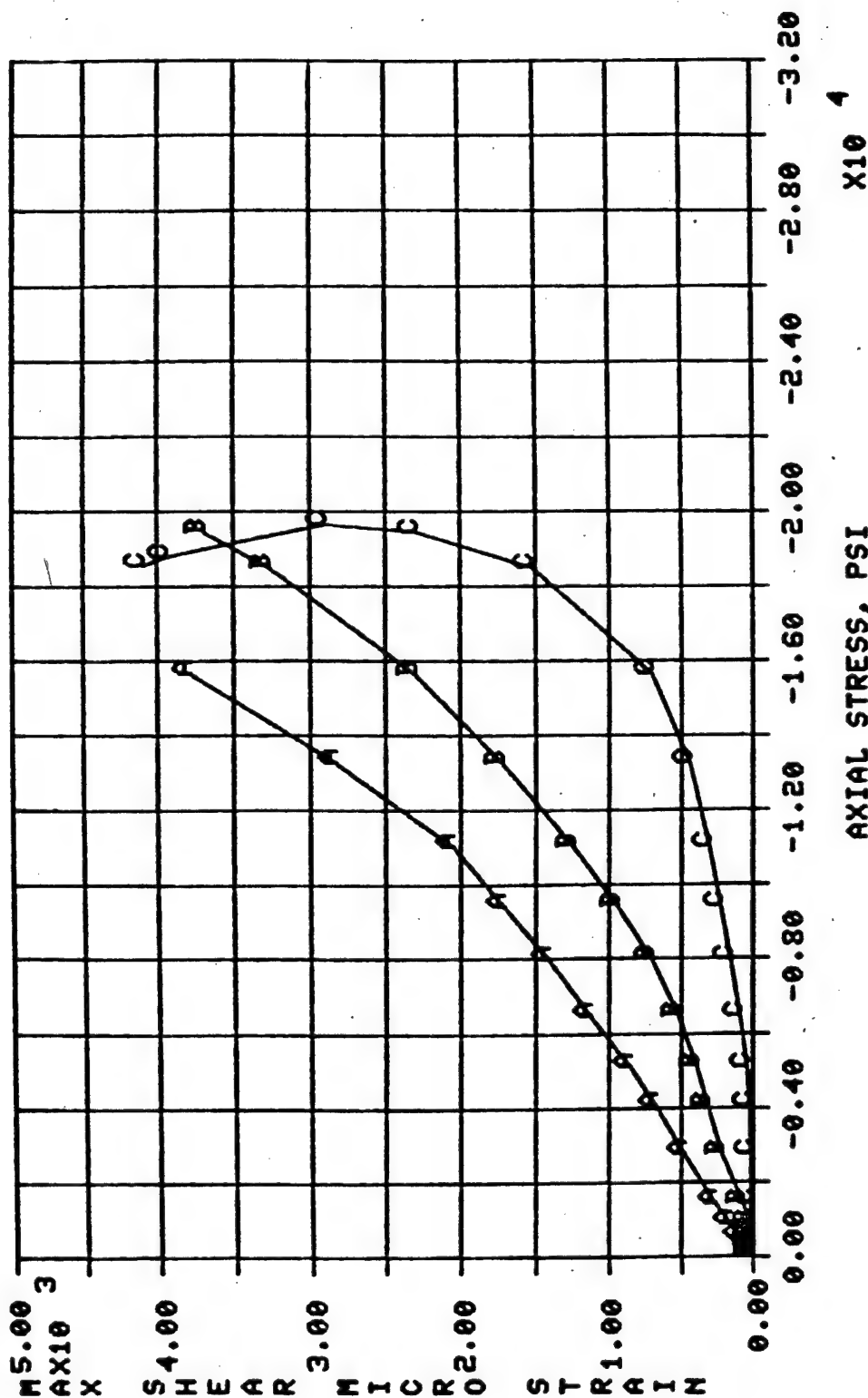


Figure 13 Test 1. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8



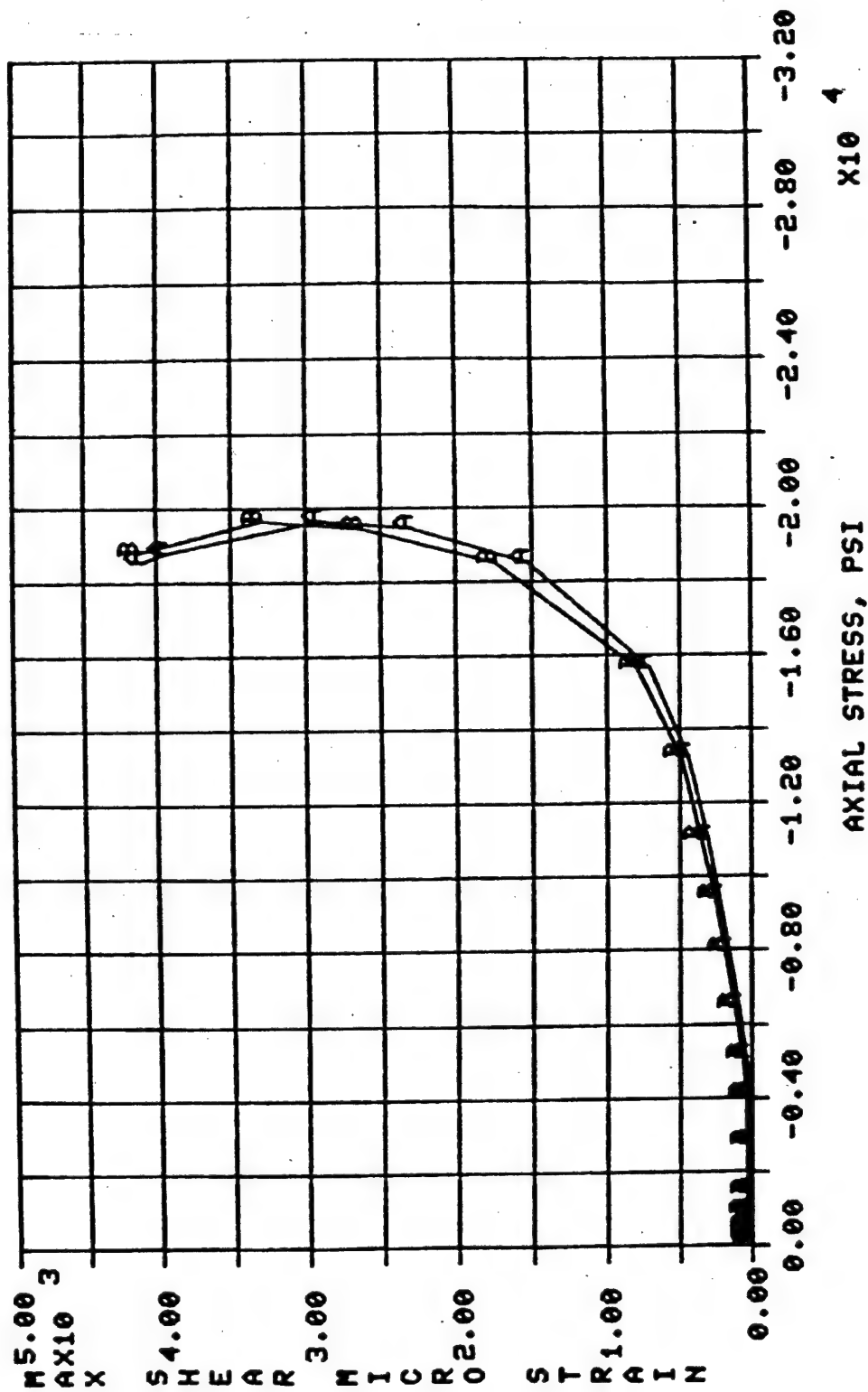


Figure 15 Test 1. Layup  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5

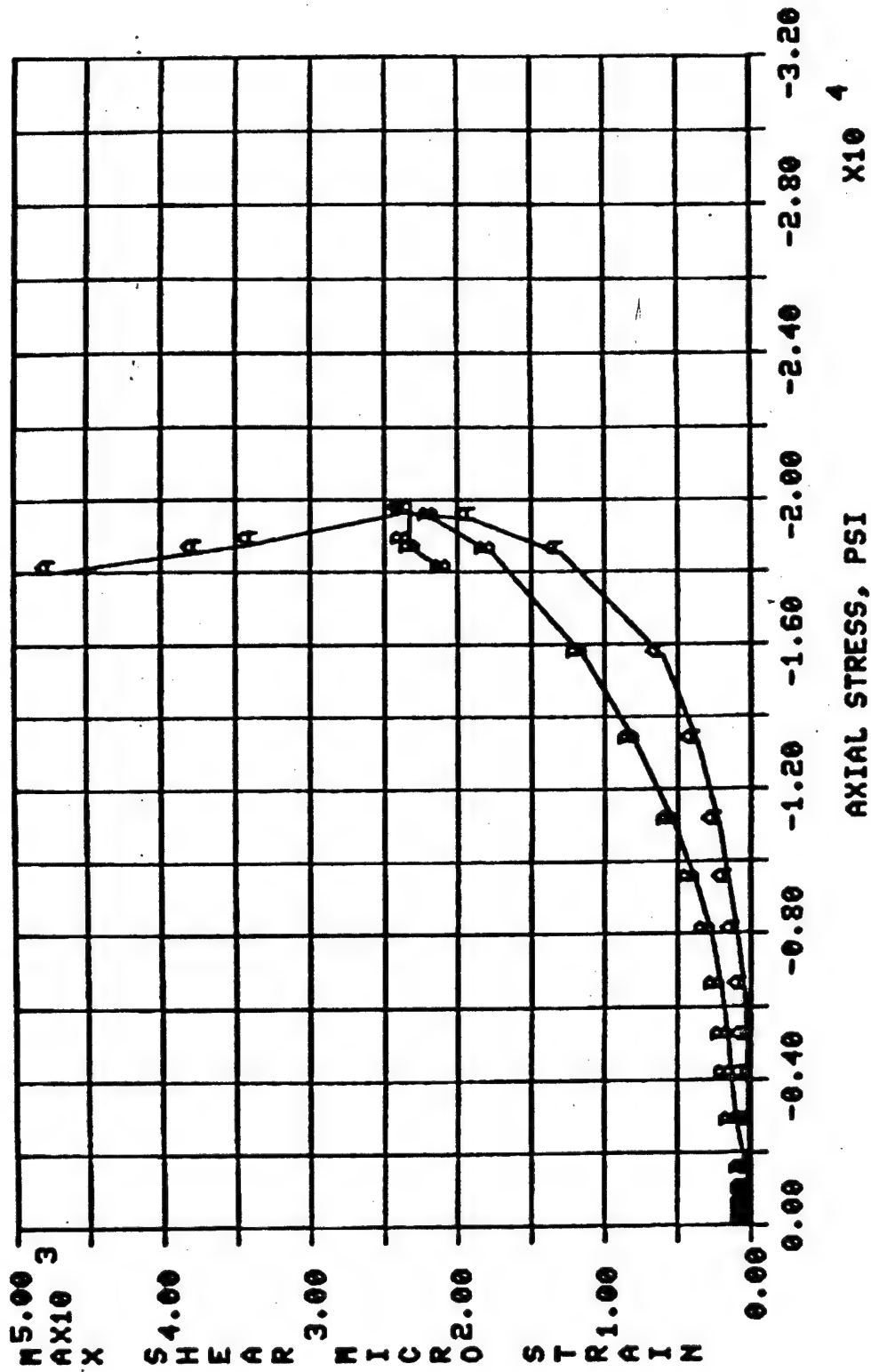


Figure 16 Test 1. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear Response, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8



Test 2 was performed on a specimen with a ply layup of  $0^\circ/\pm 45^\circ/90^\circ$  under internal pressure. Figures 17, 18 and 19 are comparison plots of axial strain, hoop strain and maximum shear strain, respectively, versus hoop stress for the four gages located at the center of the specimen on the outside surface. These strains show good agreement. Strains were not recorded for this specimen until the hoop stress level reached approximately 16,000 psi. This was presumably due to the data acquisition system operating in the automatic balance mode during the first few data scans. Figures 20, 21 and 22 are comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the two gages located at the center of the specimen but on opposite surfaces. Figures 23, 24 and 25 present comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the three gages along the top of the specimen. Two of these gages are at the same location, but on opposite surfaces. Very good agreement was found between the inside and outside gages and the maximum shear strains at all rosette locations were almost identical. Hoop stresses greater than 120,000 psi were produced by the internal pressure and final fracture was catastrophic. The specimen after failure is shown in Figure 26.

Test 3 was using a  $\pm 45^\circ$  ply layup specimen under internal pressure. A 100 pound axial load was applied to the specimen prior to the internal pressure. This axial load was kept constant throughout the testing. Data was recorded at only one scan during this test. Figures 27, 28 and 29 present comparisons for axial, hoop and maximum shear strains, respectively, versus hoop stress for the outside center gages. Figures 30, 31 and 32 are comparison plots for axial, hoop and maximum shear strains, respectively, versus hoop stress for the gage locations at the center of the specimen, but on opposite surfaces. Figures 33, 34 and 35 present the comparison plots for

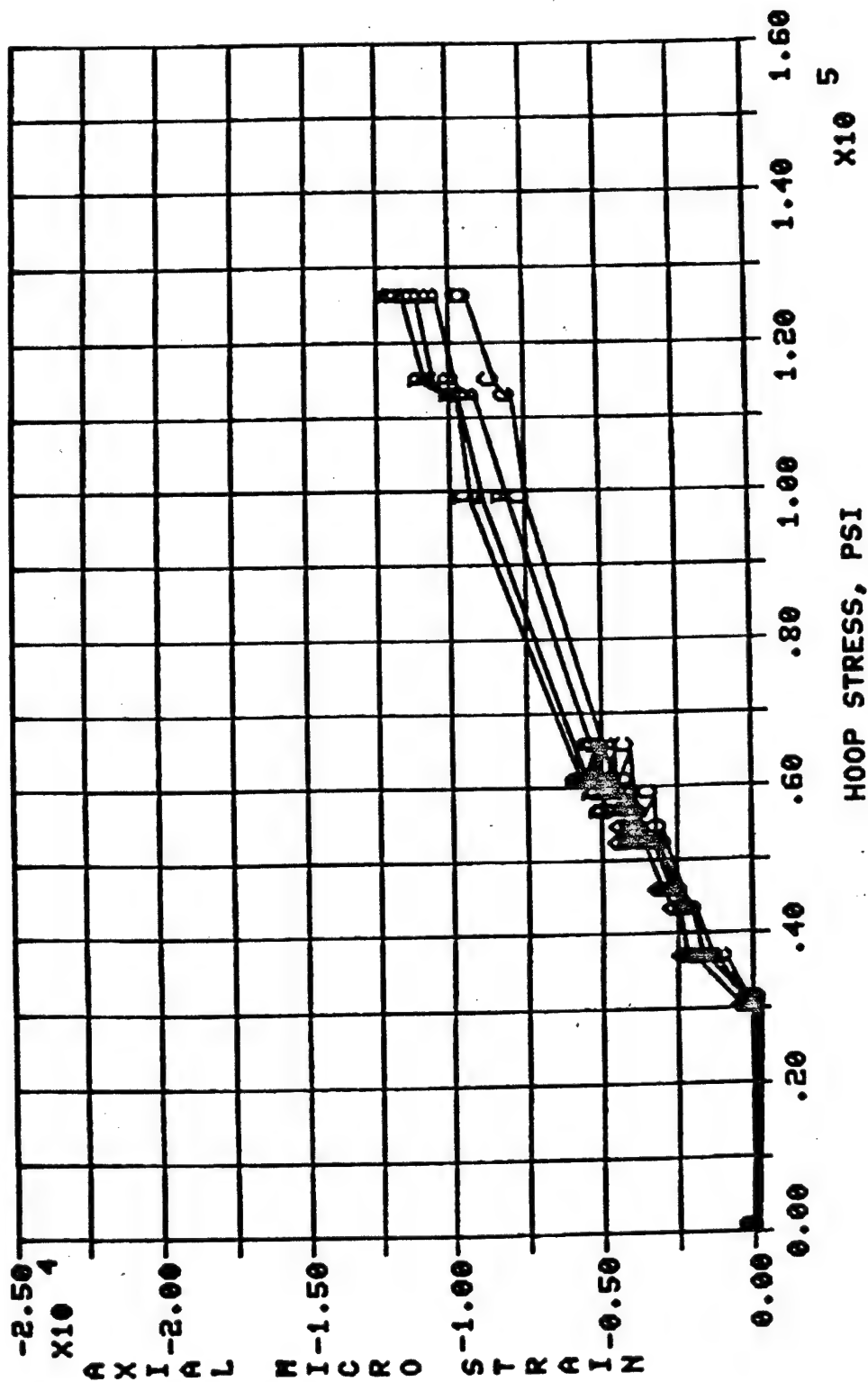


Figure 17 Test 2. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Int.  
Pressure Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4

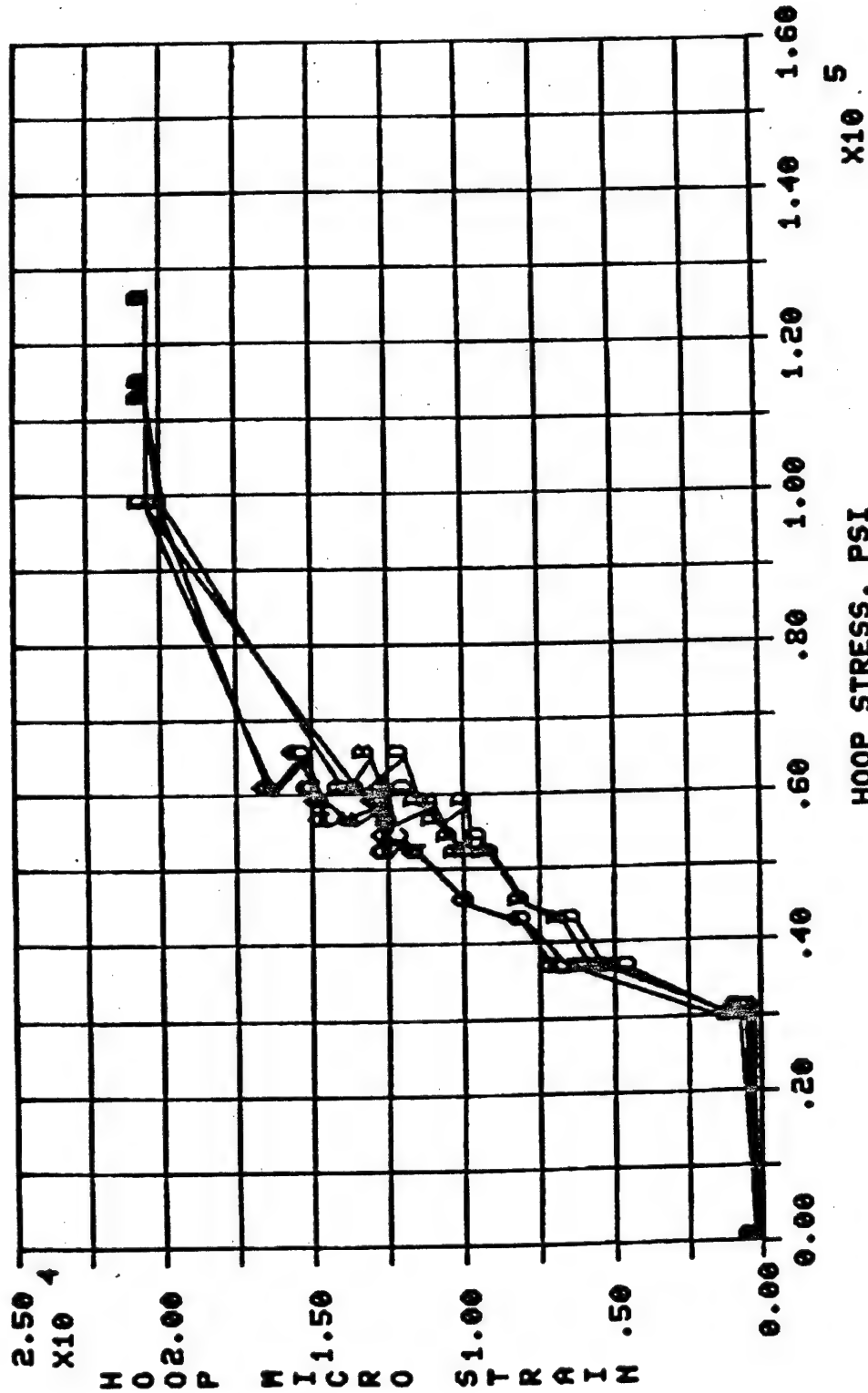


Figure 18 Test 2. Layup 0°/±45°/90° Int.  
Pressure Hoop Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4

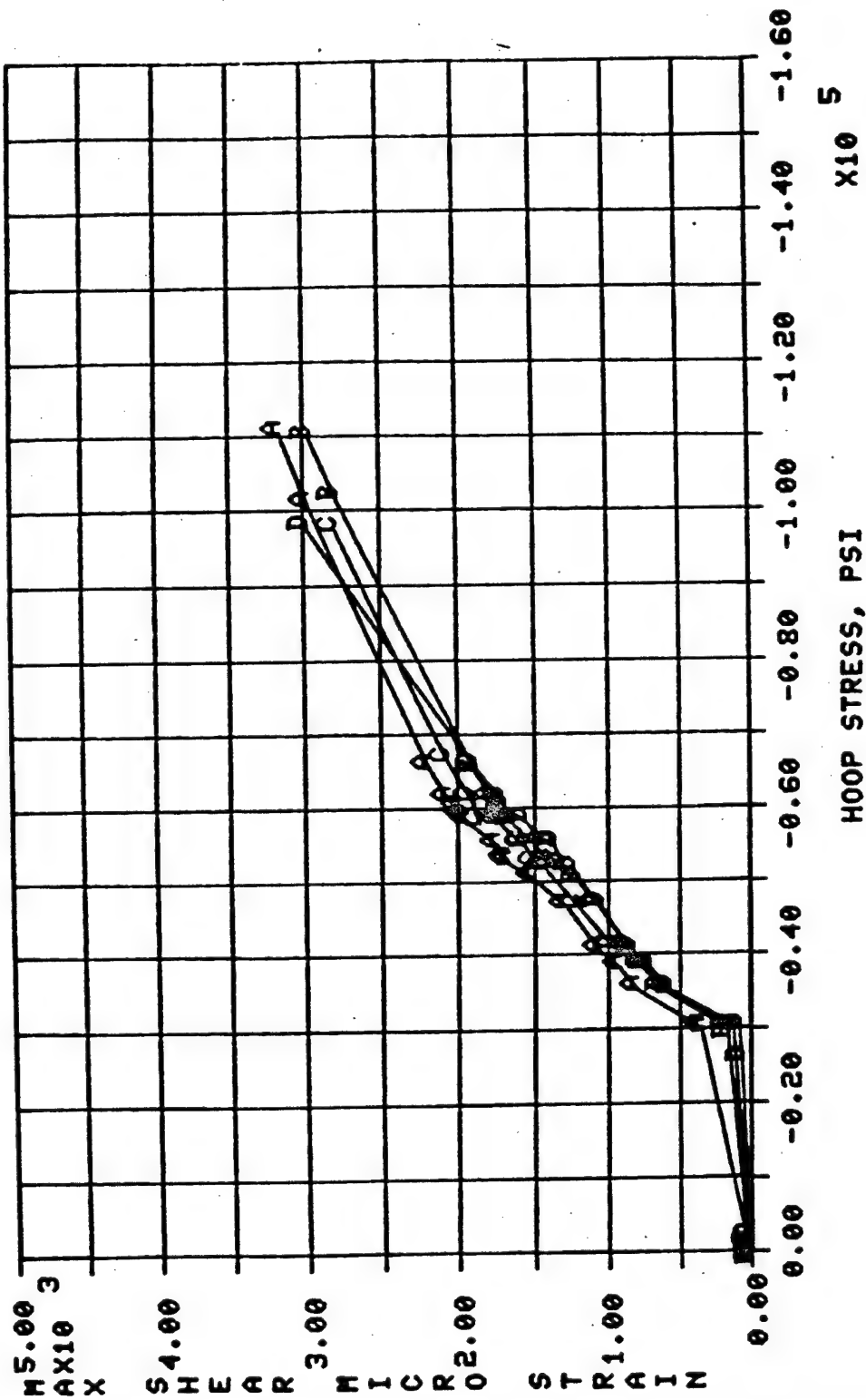


Figure 19 Test 2. Layout 0°/±45°/90° Int. Pressure  
Max. Shear, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4

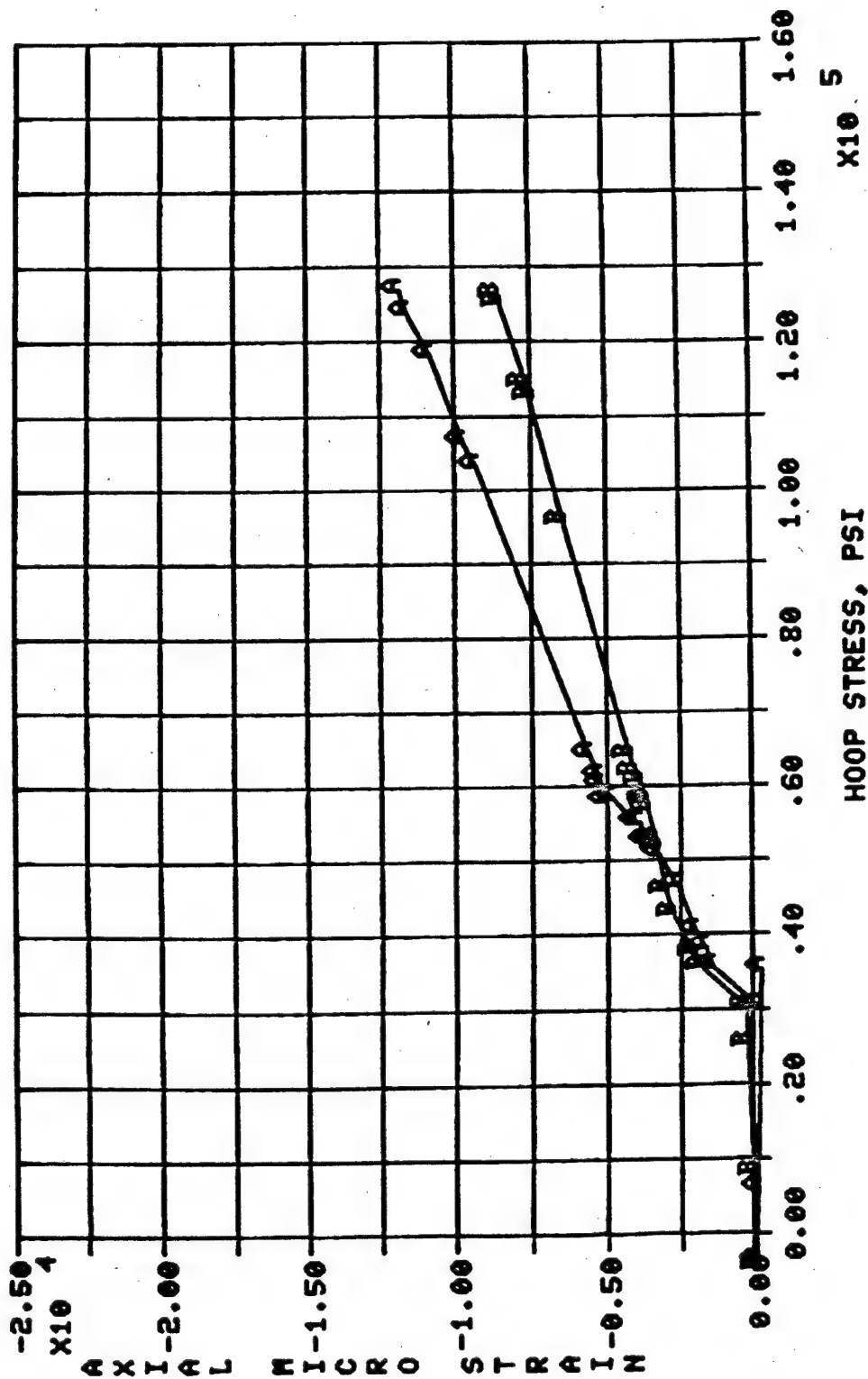


Figure 20 Test 2. Layup 0°/±45°/90° Int. Pressure  
Axial Response, Inside/Outside Rosettes  
Least Squares Fit  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

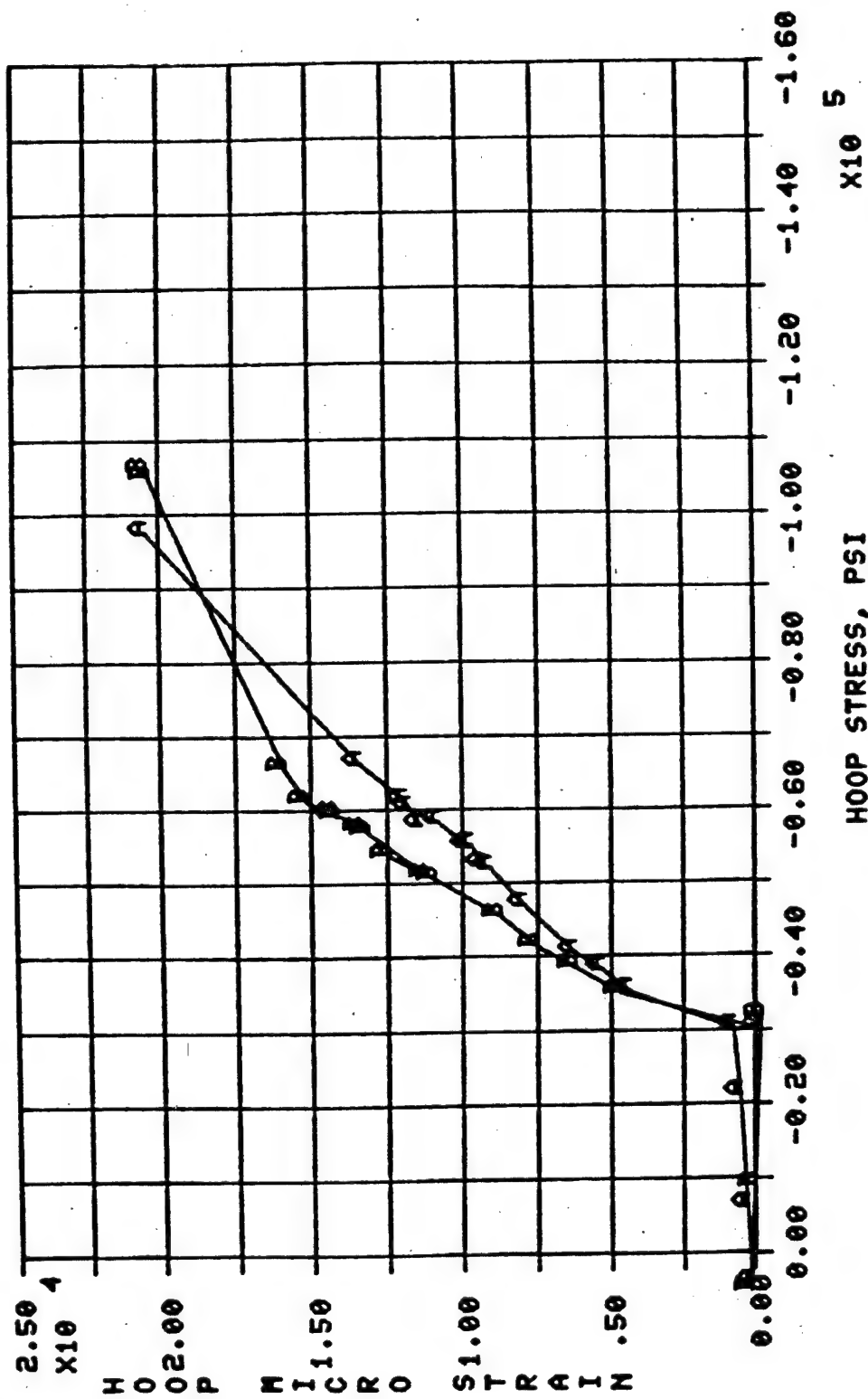


Figure 21 Test 2. Layup  $0^\circ/\pm 45^\circ/90^\circ$  Int. Pressure  
Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

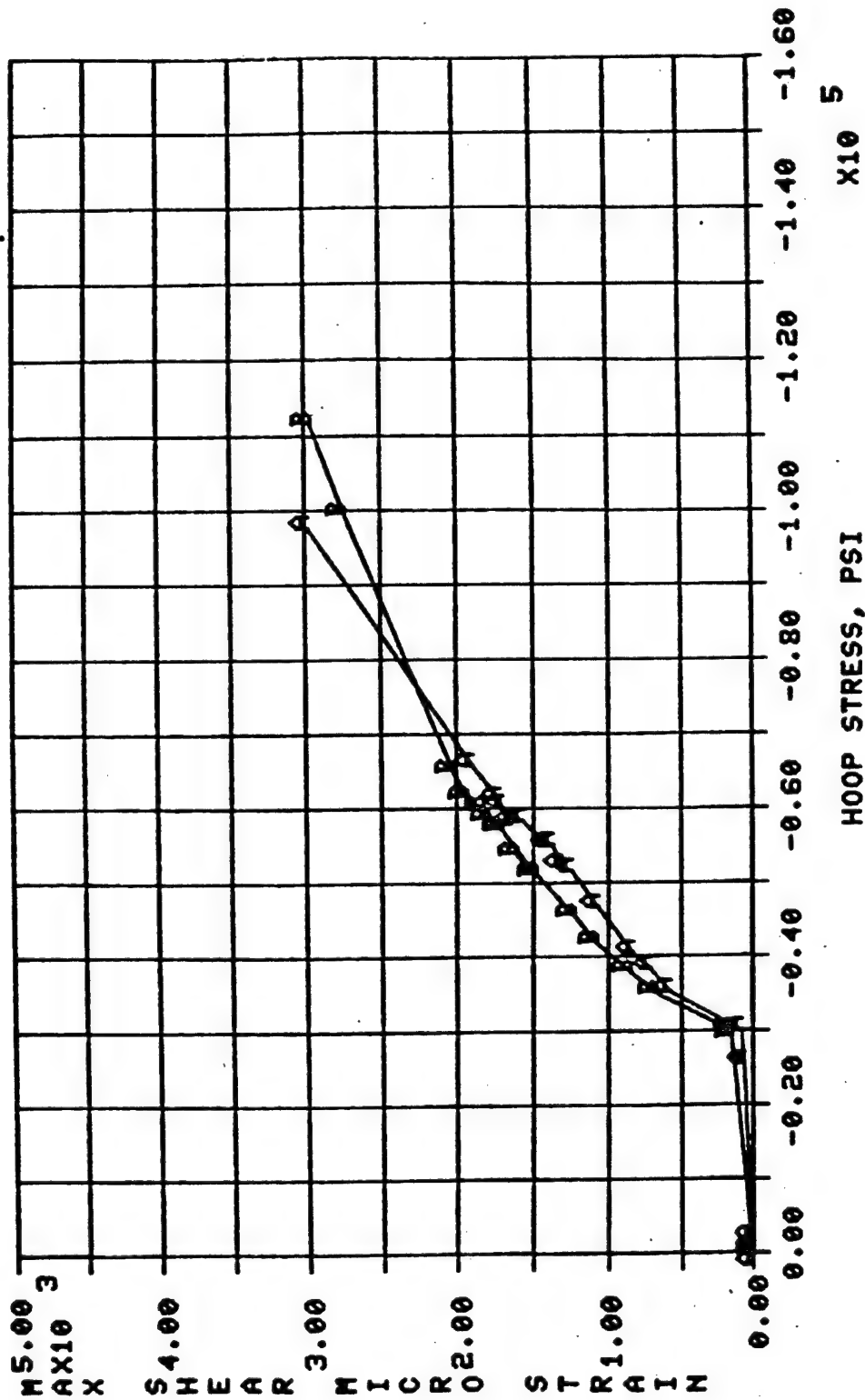


Figure 22 Test 2. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Int. Pressure  
Max. Shear, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

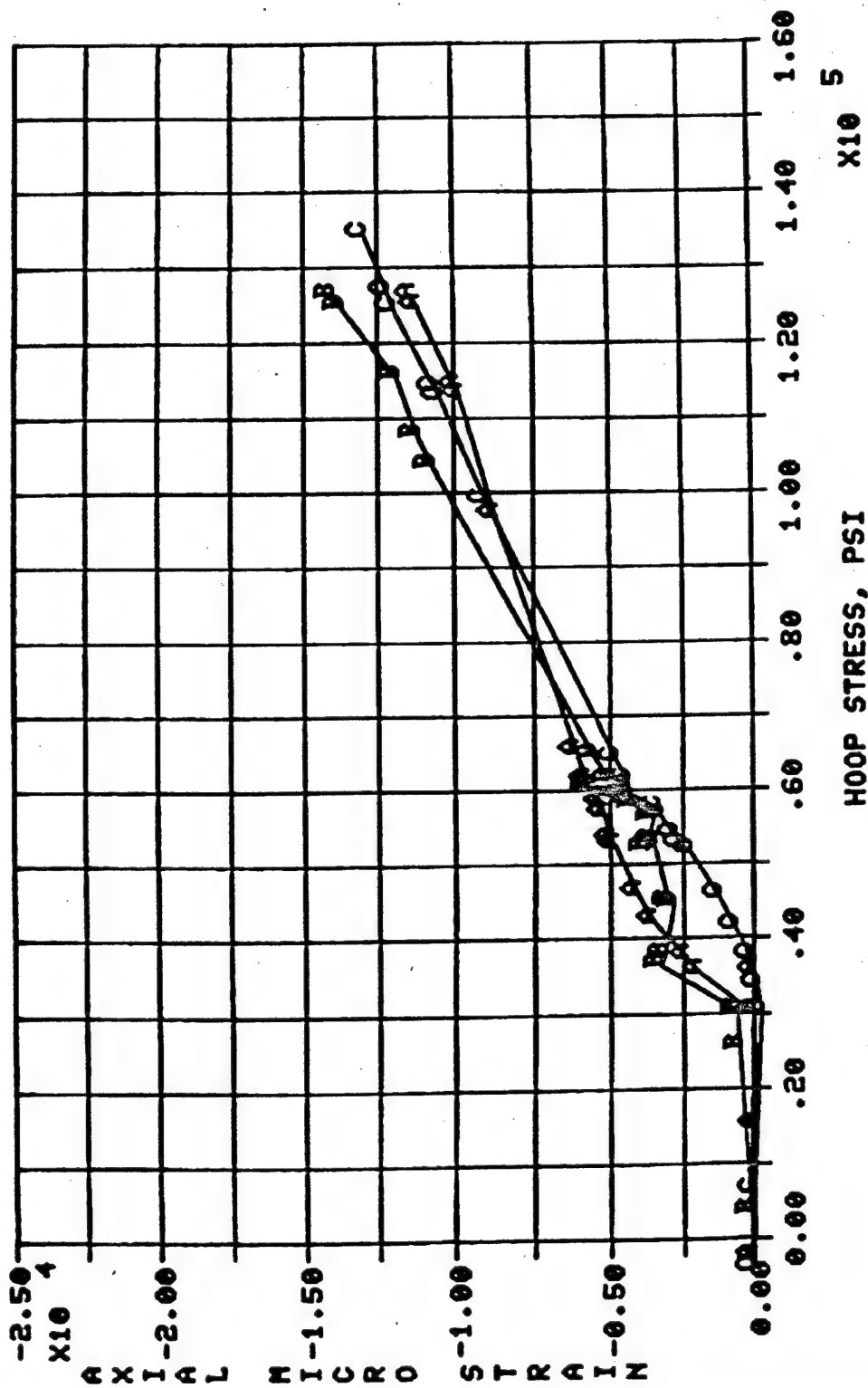


Figure 23 Test 2. Layup  $0^\circ/\pm 45^\circ/90^\circ$  Int. Pressure  
Axial Response, Edge Rosettes  
Least Squares Fit  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8



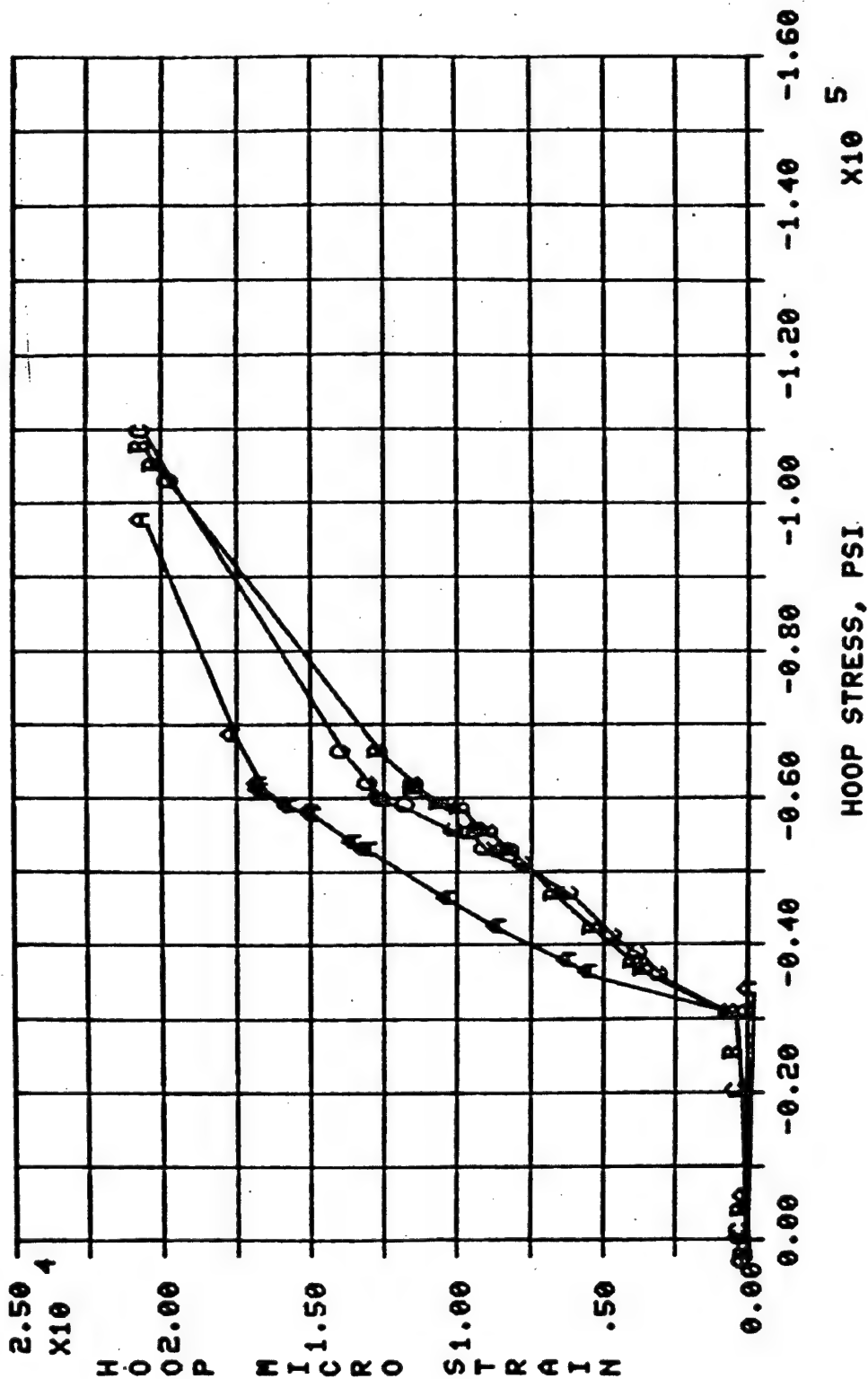


Figure 24 Test 2. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Int. Pressure  
Hoop Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

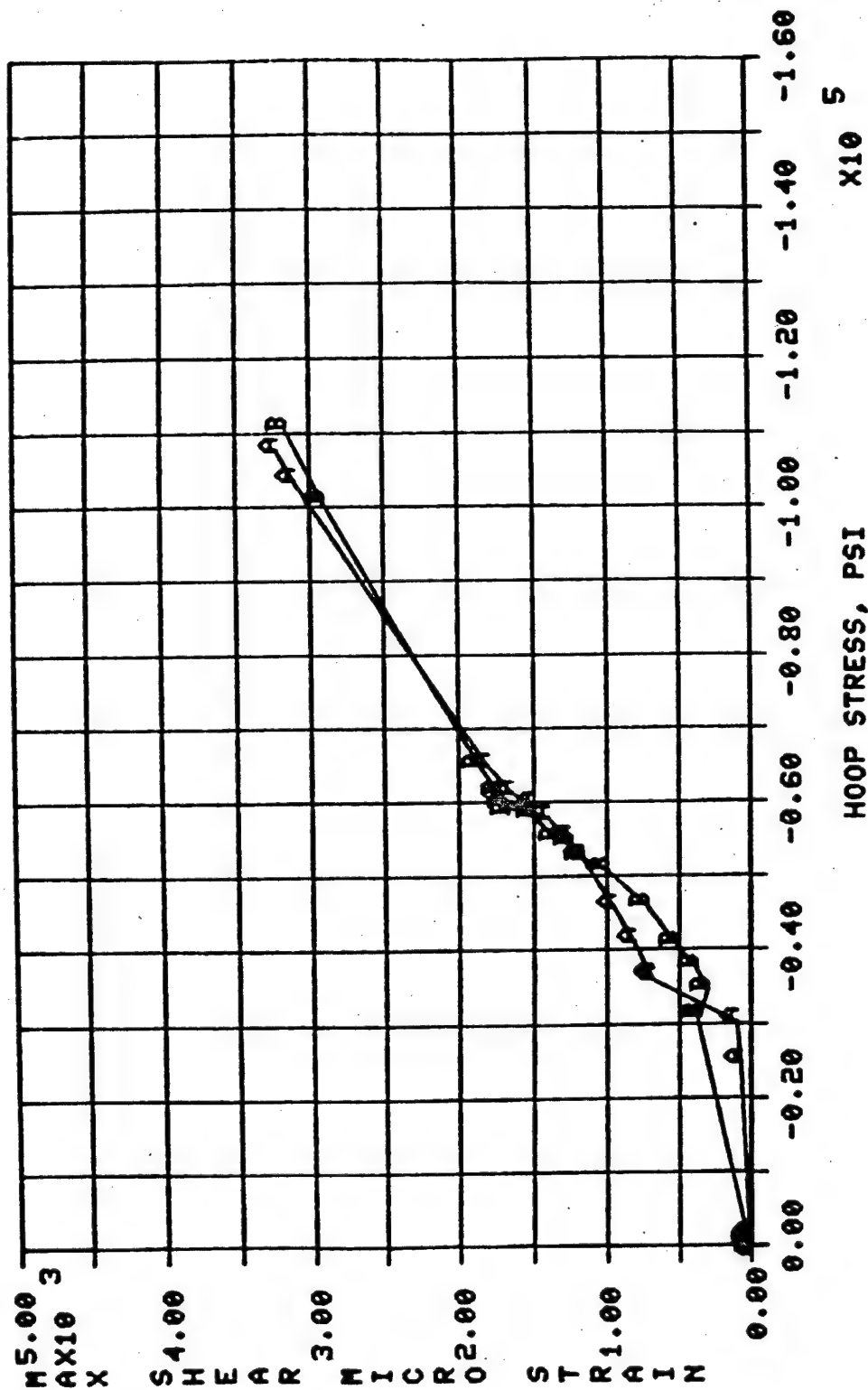


Figure 25 Test 2. Layup 0°/±45°/90° Int. Pressure  
Max. Shear, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8



Figure 26    Test Specimen No. 2 After Rupture by  
Internal Pressure. Ply layup is  
 $0^\circ/\pm 45^\circ/90^\circ$ .

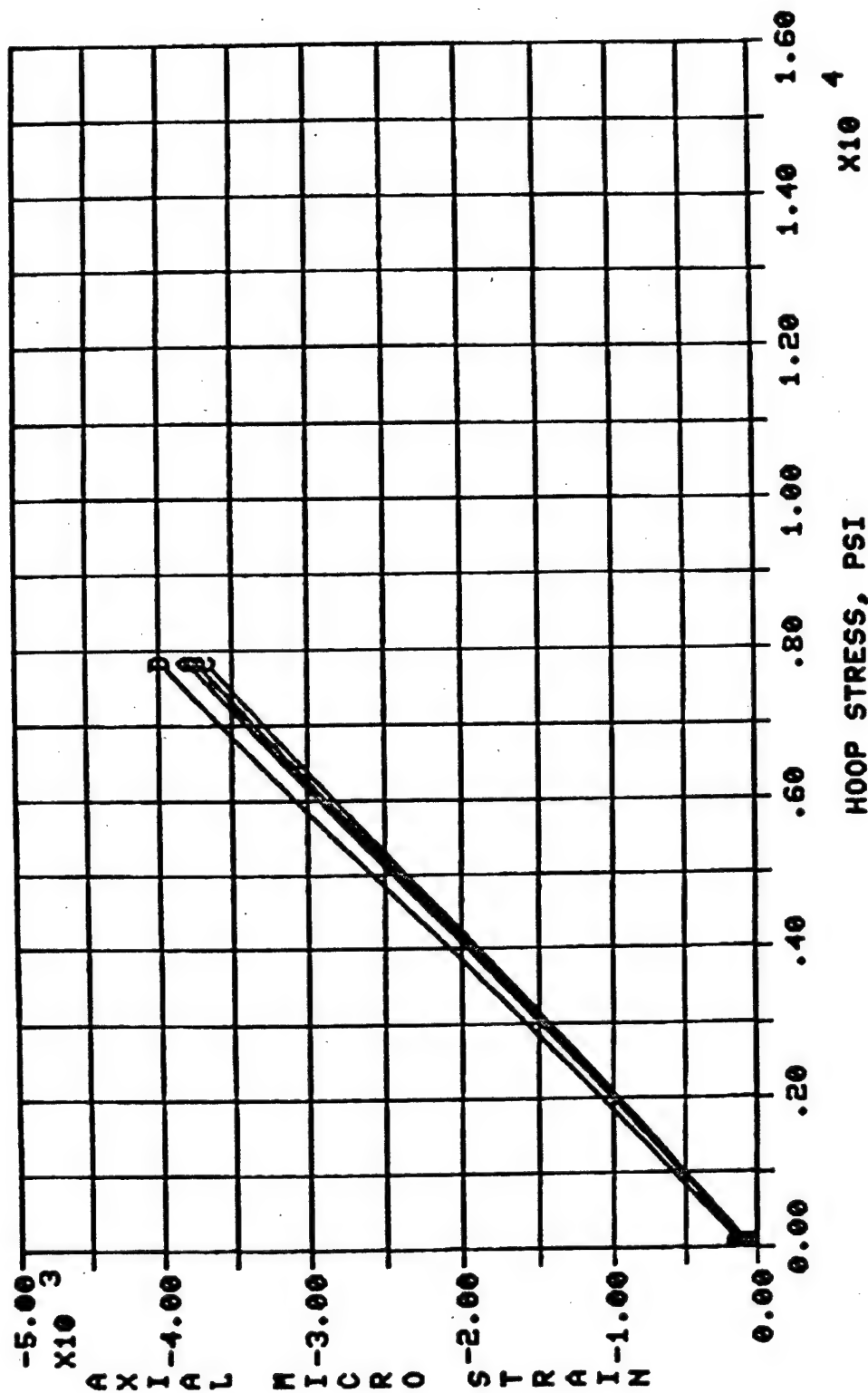


Figure 27 Test 3.  $\pm 45^\circ$  Int. Pressure  
Axial Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

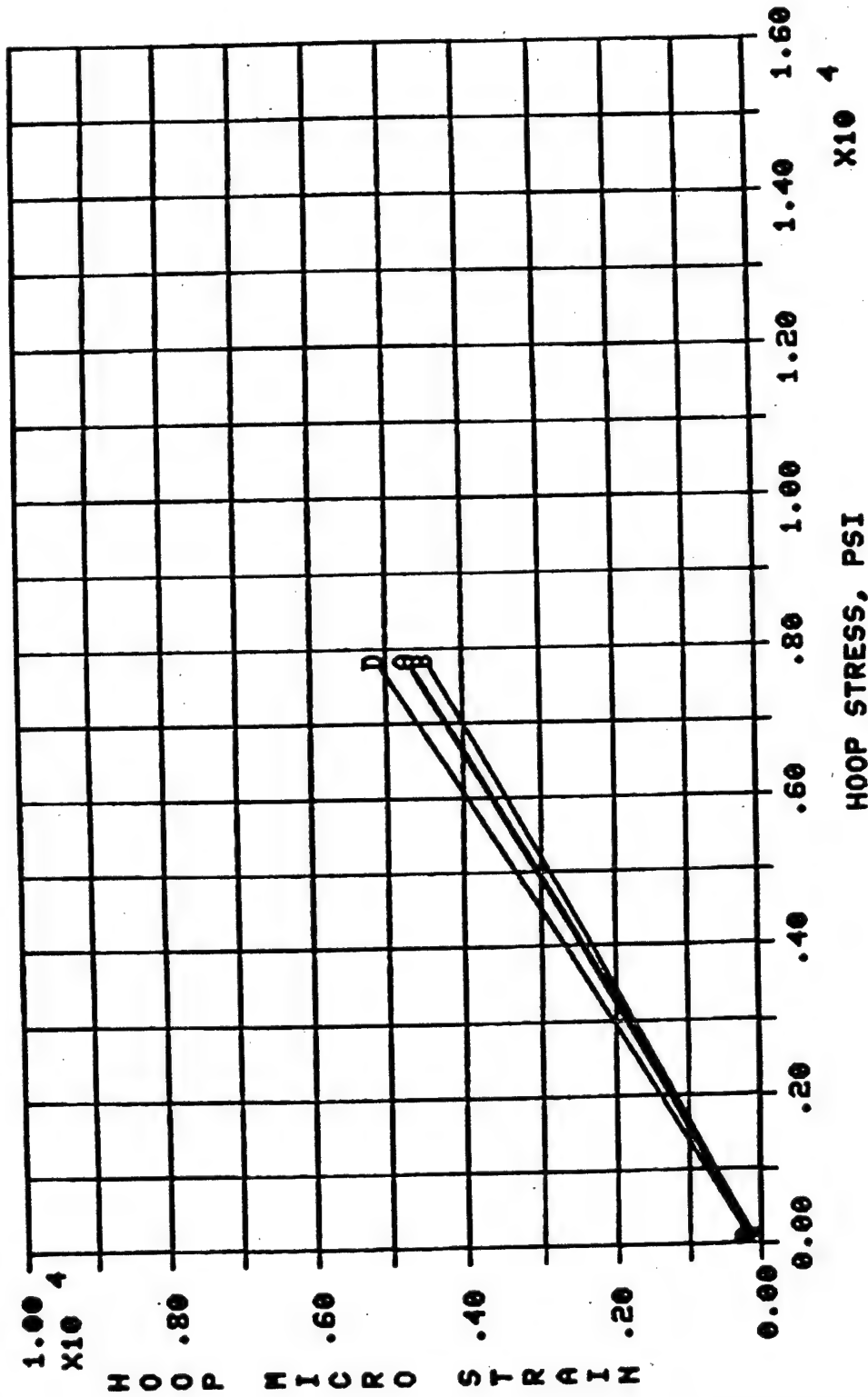


Figure 28 Test 3.  $\pm 45^\circ$  Int. Pressure  
Hoop Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4

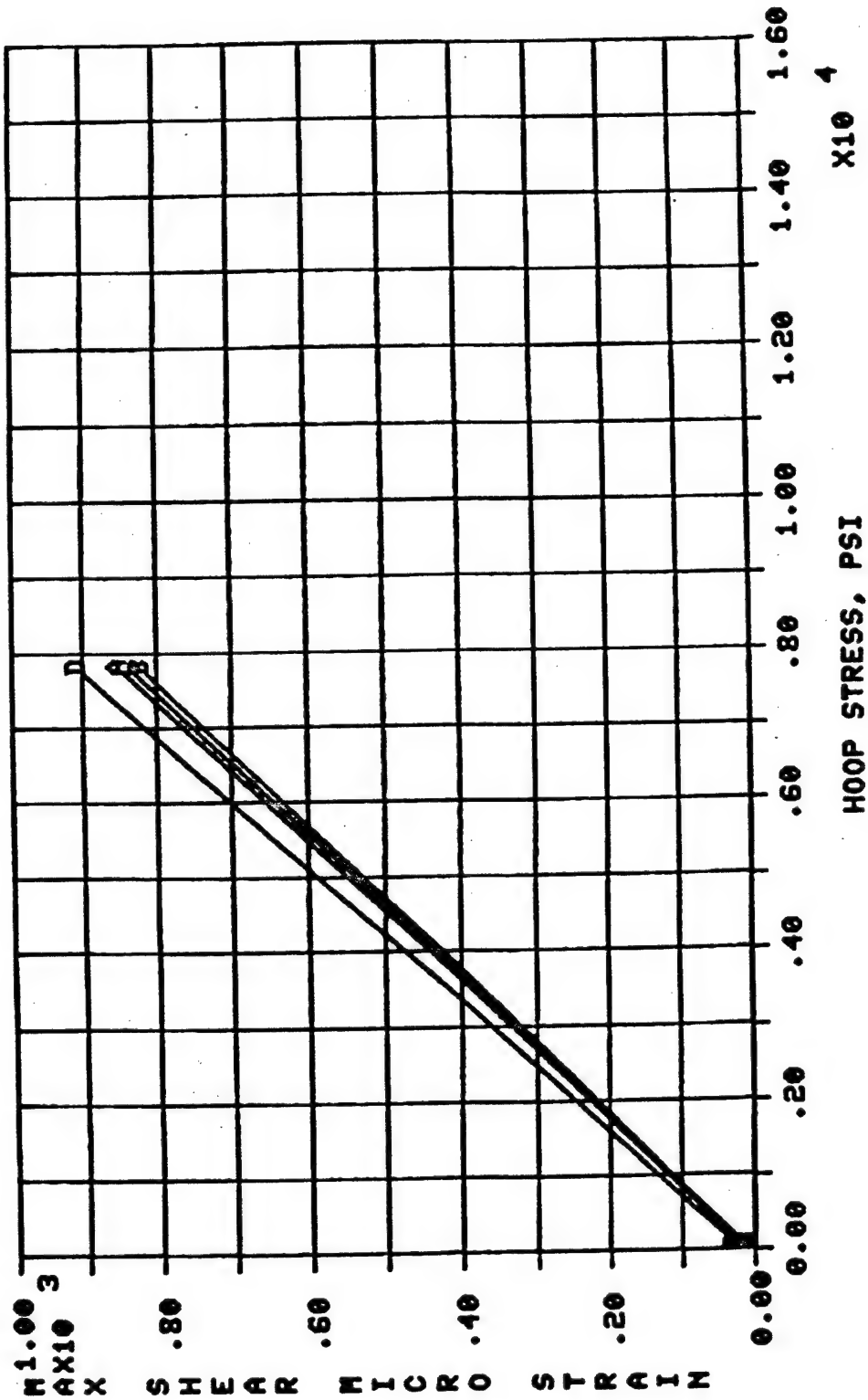


Figure 29 Test 3.  $\pm 45^\circ$  Int. Pressure  
Max. Shear, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

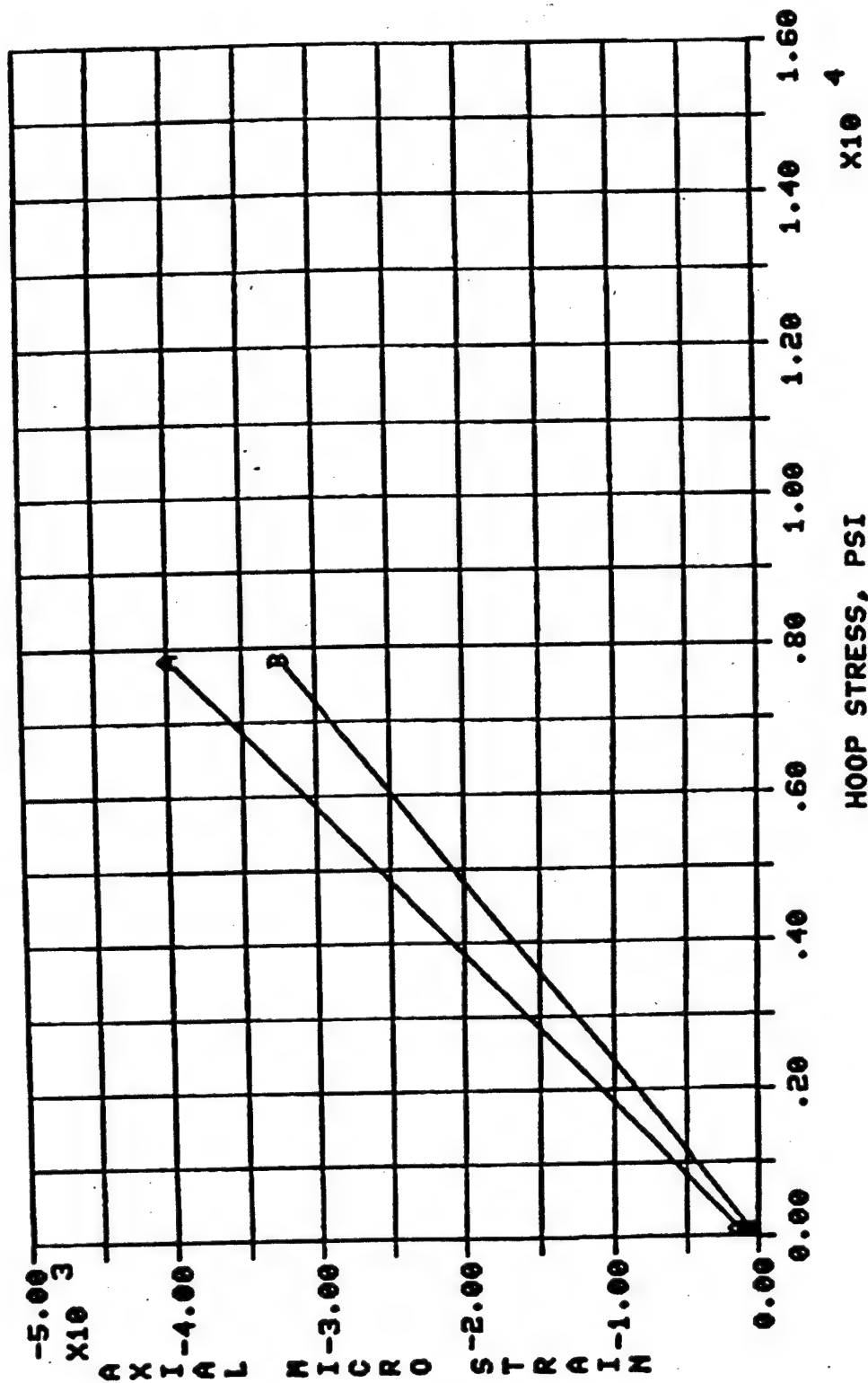


Figure 30 Test 3.  $\pm 45^\circ$  Int. Pressure Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

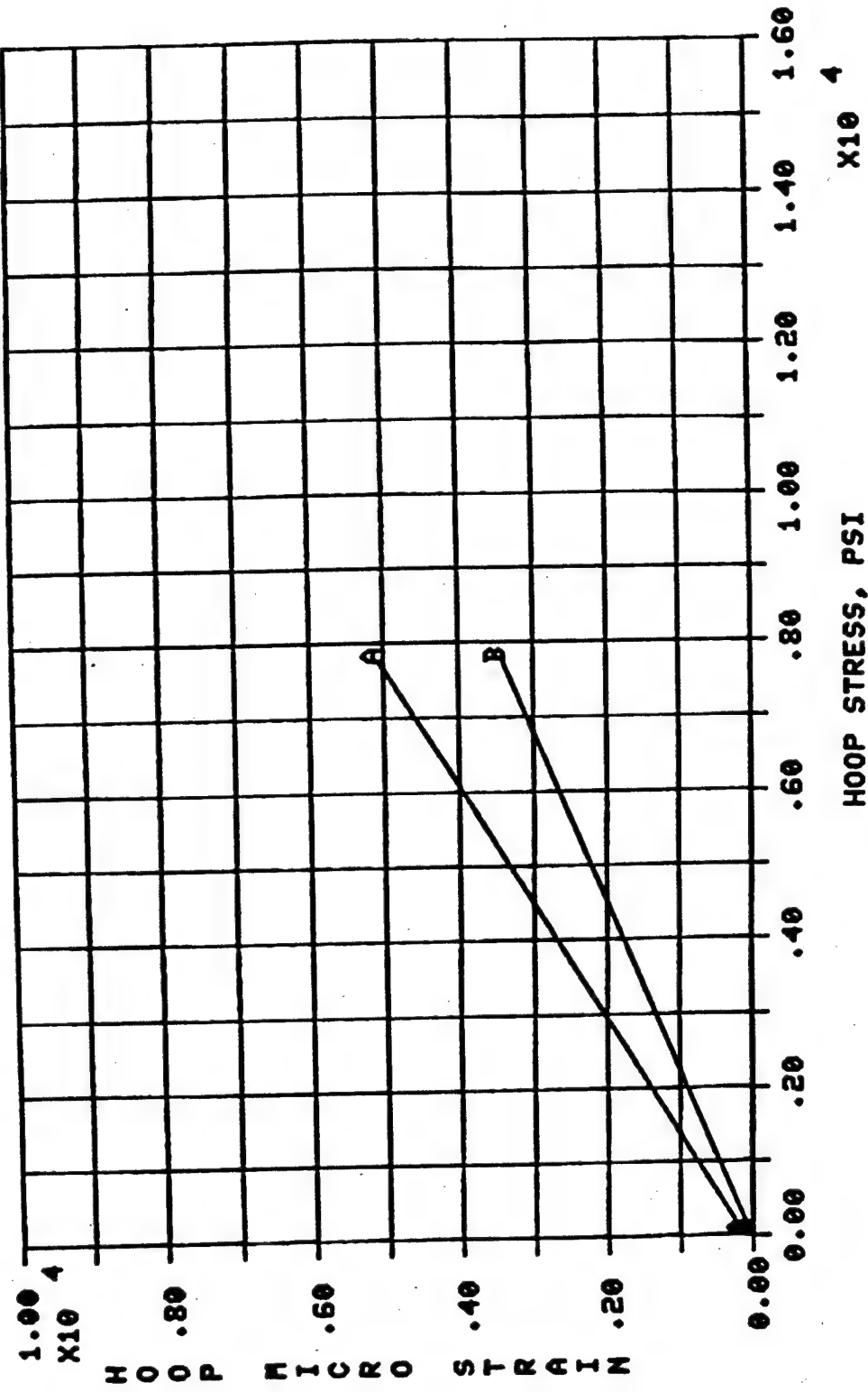


Figure 31 Test 3. ±45° Int. Pressure Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)



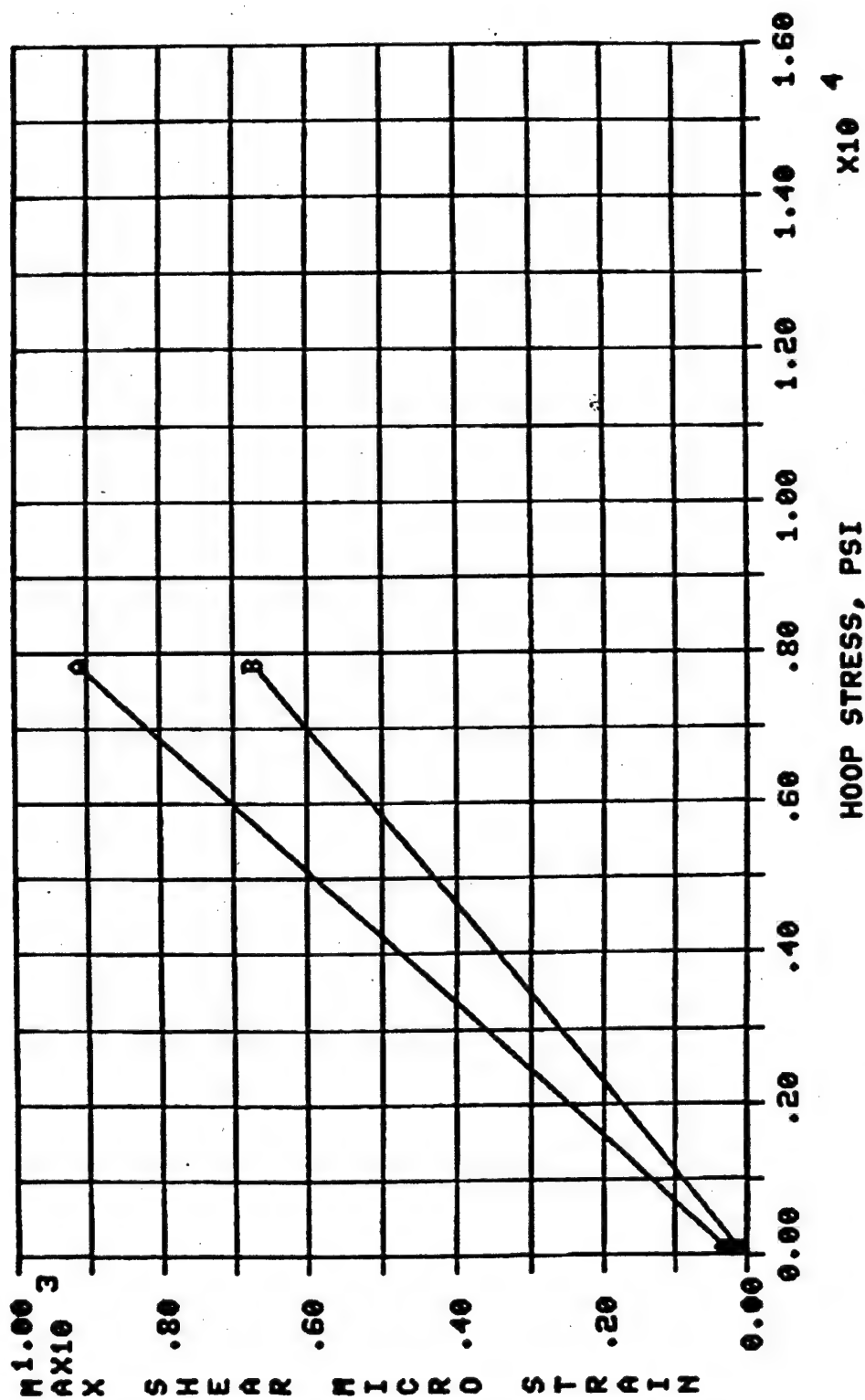


Figure 32 Test 3.  $\pm 45^\circ$  Int. Pressure Max.  
Shear, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

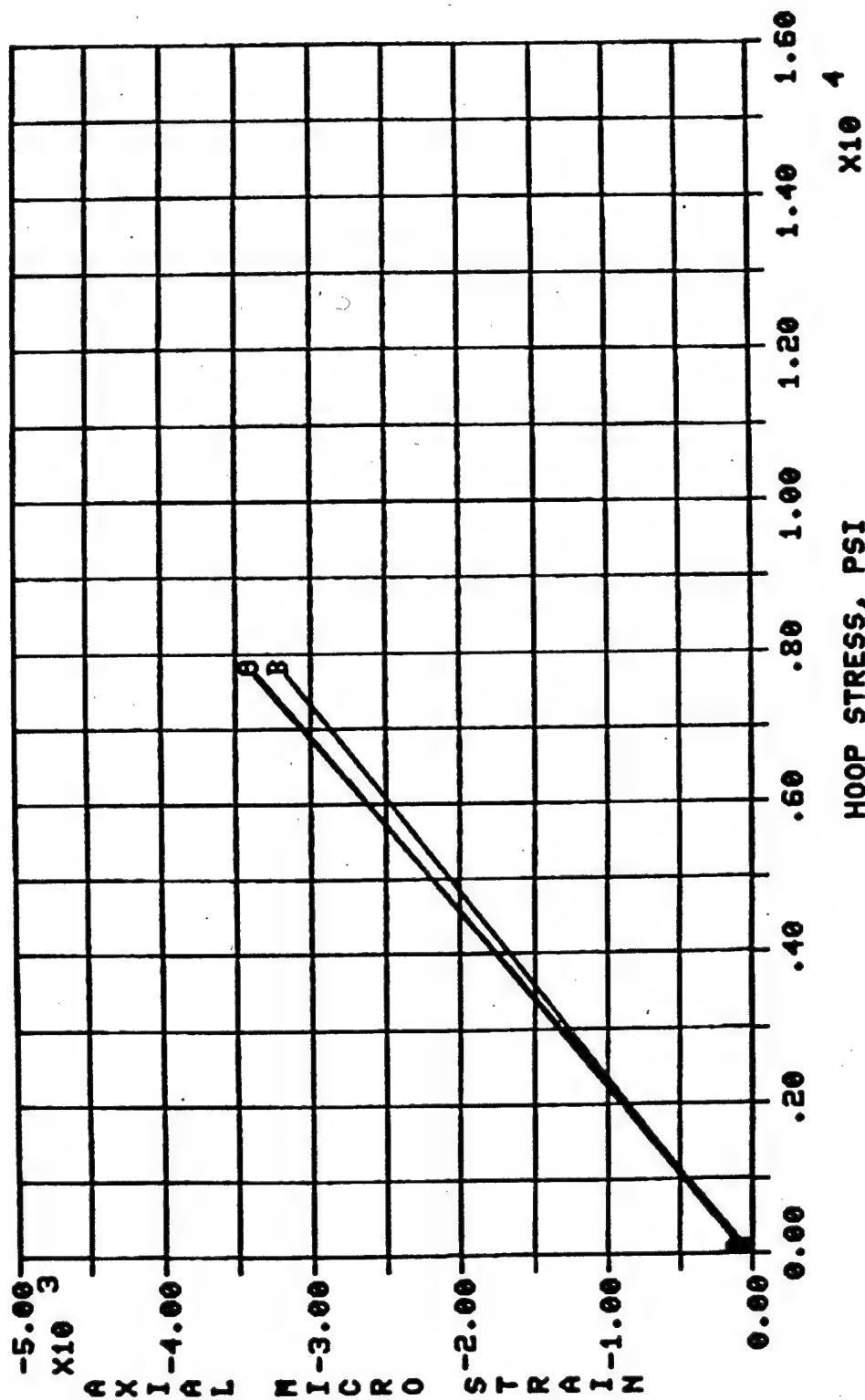


Figure 33 Test 3.  $\pm 45^\circ$  Int. Pressure  
Axial Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

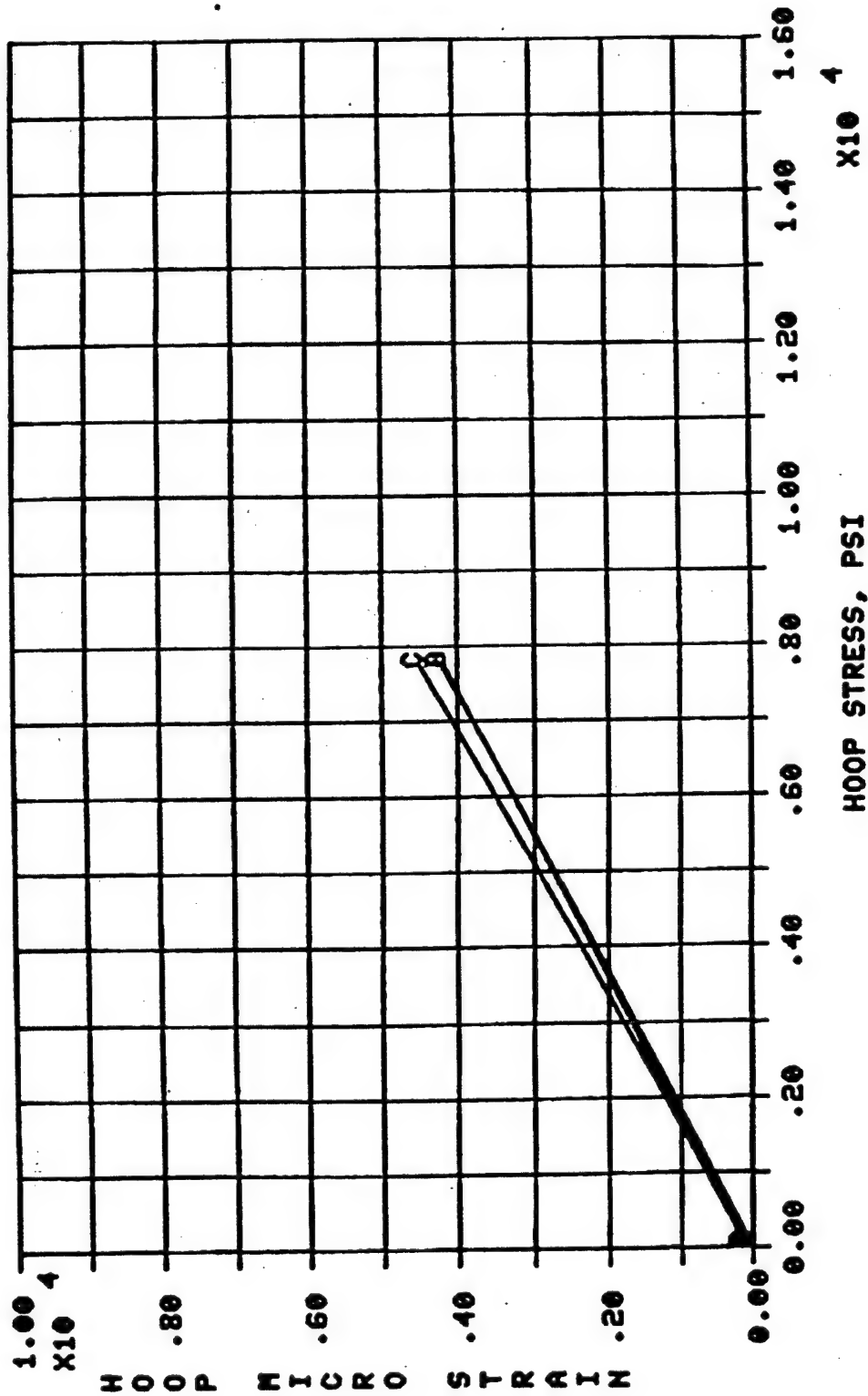


Figure 34 Test 3.  $\pm 45^\circ$  Int. Pressure  
Hoop Response, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

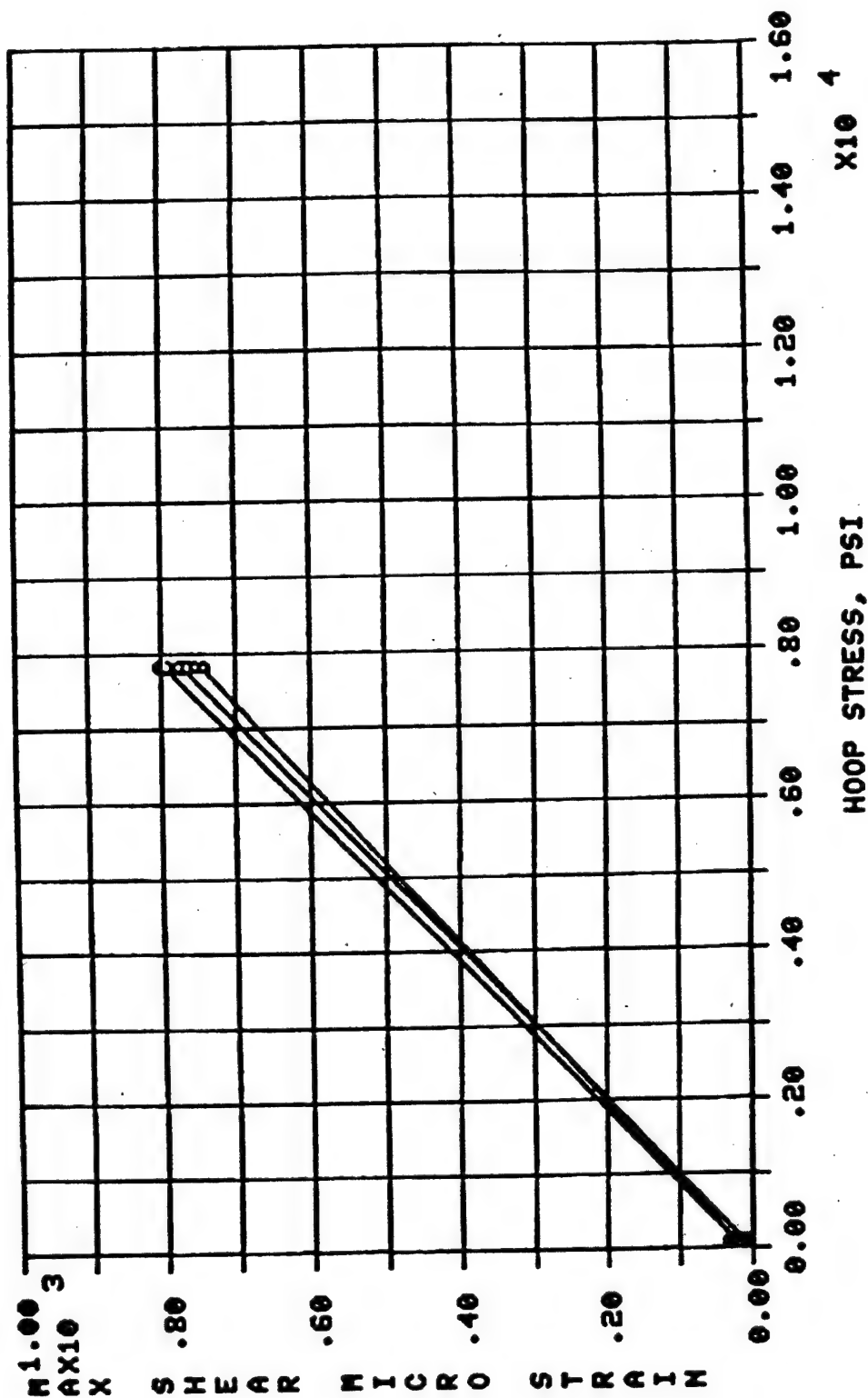


Figure 35 Test 3.  $\pm 45^\circ$  Int. Pressure  
Max. Shear, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

axial, hoop and maximum shear strains, respectively, versus hoop stress for the gage locations along the edge of the specimen. These plots show excellent agreement for axial and hoop strains for all gages located on the outside surface. Figures 30, 31 and 32 show that some bending was occurring. Maximum shear strains at all rosette locations were in very good agreement. Figure 36 shows the specimen after rupture by the internal pressure.

Test 4 consisted of applying three different partial compressions to the same specimen. The specimen layup was  $\pm 45^\circ$ . For the first partial compression, which was designated as Test 4-A, the axial stress was taken to approximately 5,300 psi. The resulting strain versus axial stress curves are given in Figures 37 through 45. During Test 4-B, the axial stress reached 10,800 psi, twice the value of Test 4-A. Figures 46, 47 and 48 present the comparison plots for axial, hoop and maximum shear strains, respectively, for the locations along the outside center of the specimen. Figures 49, 50 and 51 present the corresponding information for the two gages located at the same location but on the inside and outside surfaces. Figures 52, 53 and 54 are comparison plots for the edge locations. Comparing the figures for Test 4-B (Figures 46 through 54) with those of Test 4-A (Figures 37 through 45) shows excellent agreement between the two tests. This indicates the tests were repeatable for this specimen up to at least 5,300 psi axial stress. These two tests show considerable scatter between the four gages located on the outside surface along the center of the specimen. Scatter of data is also seen between the edge gage locations. The comparison between inside and outside gage results (see Figures 49, 50 and 51) shows little bending is occurring at this location. Figures 55, 56 and 57 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the locations along the outside

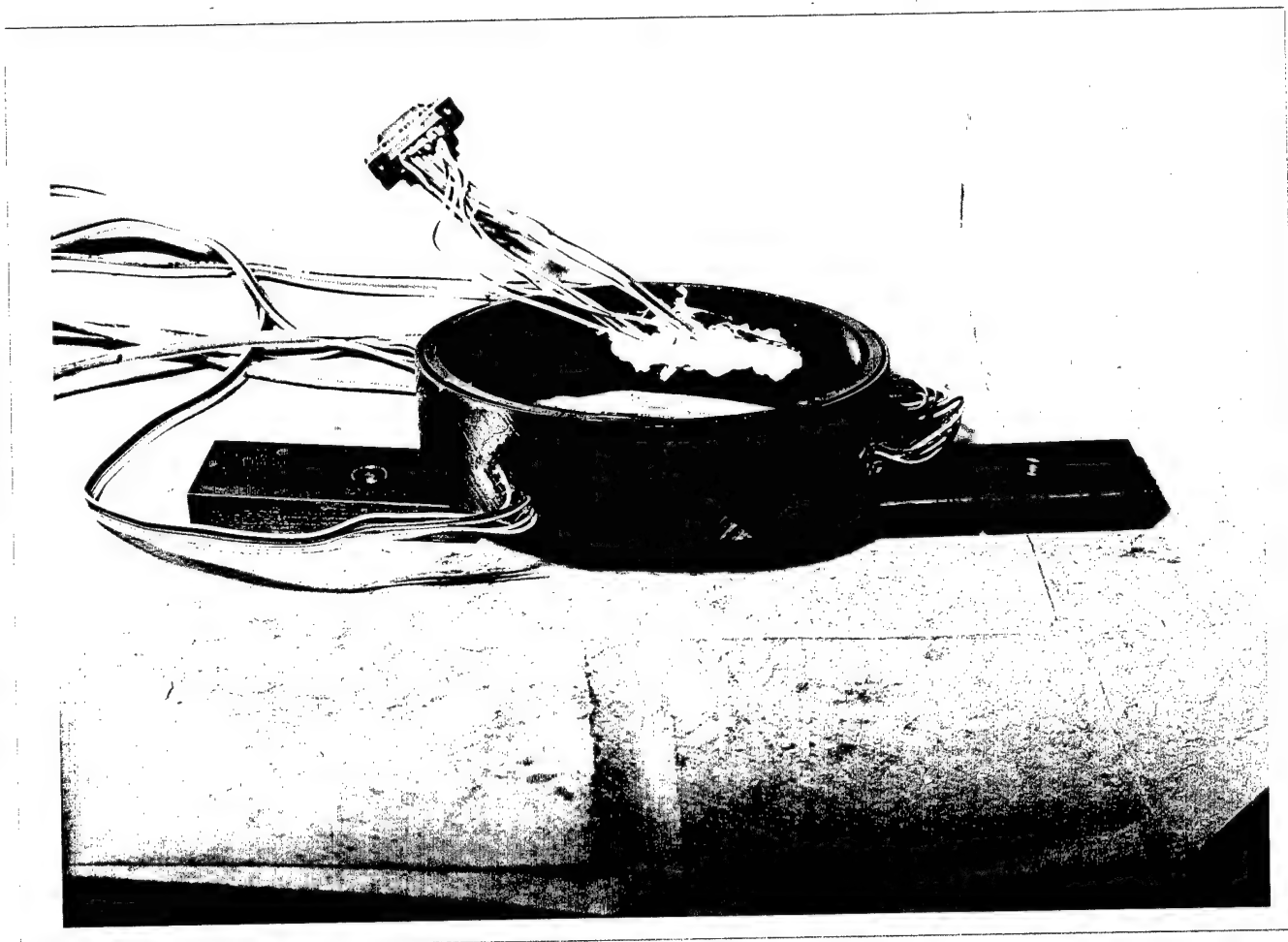


Figure 36    Test Specimen No. 3 After Rupture by  
Internal Pressure.    Ply Layup is  $\pm 45^\circ$ .

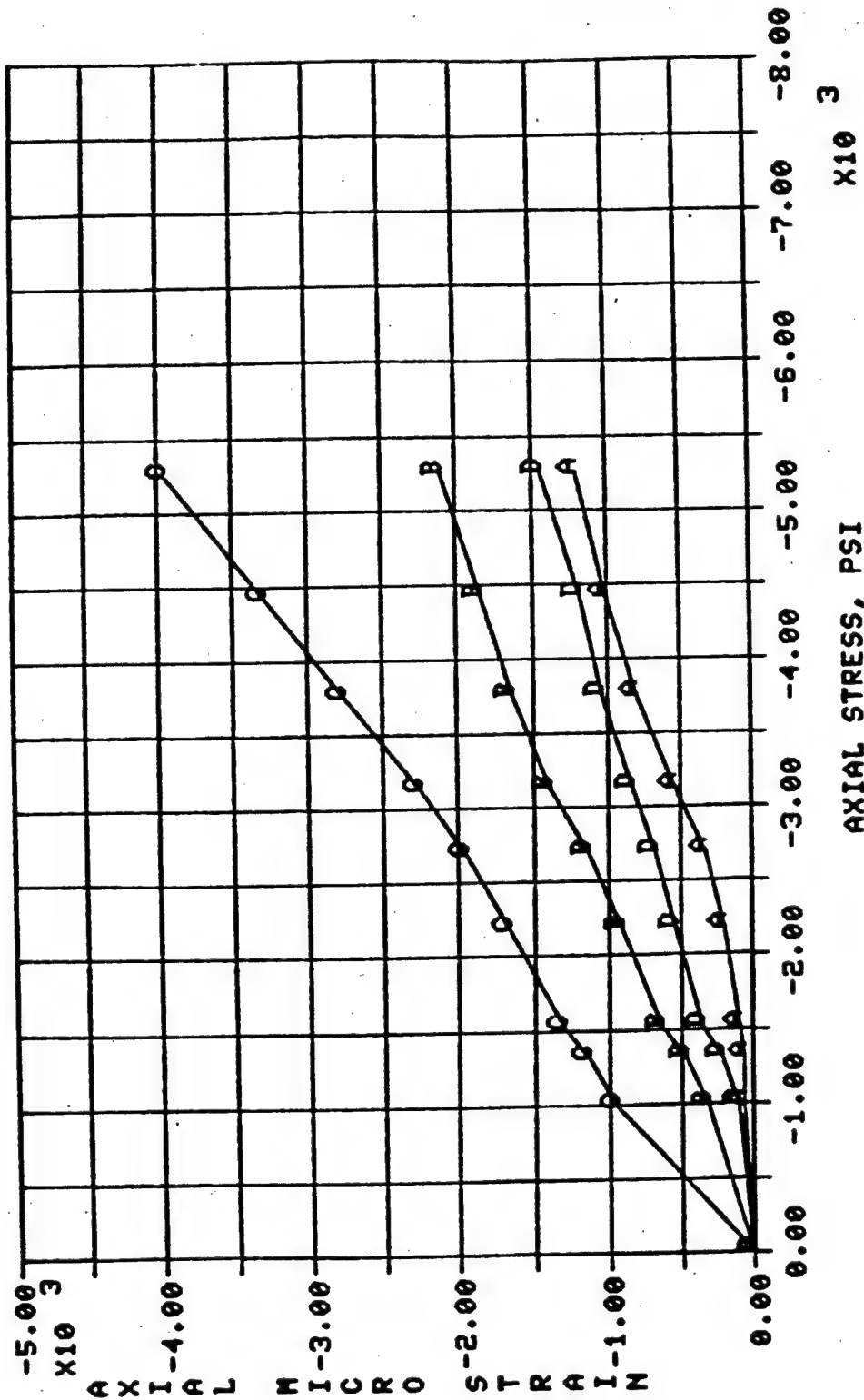


Figure 37 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

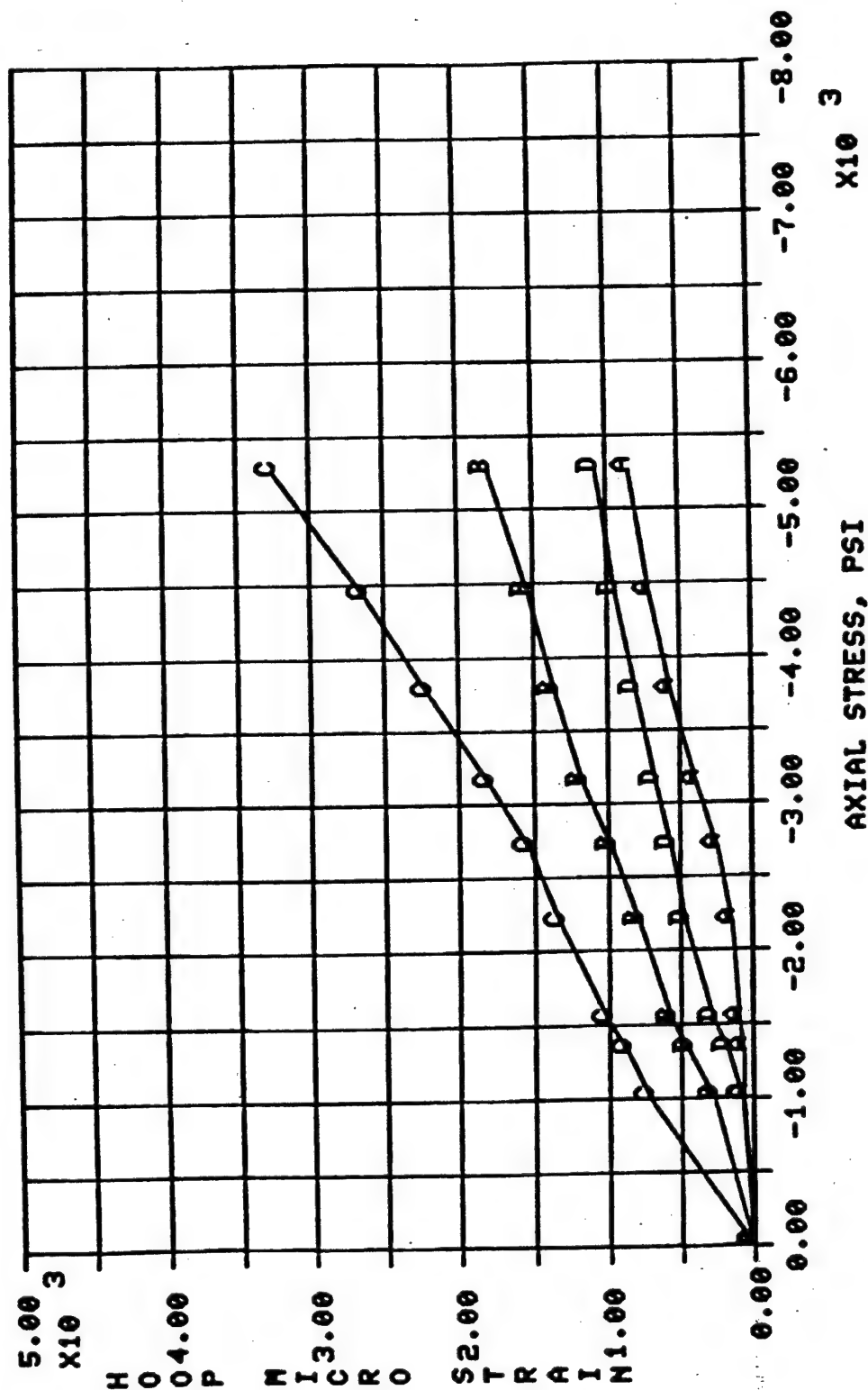


Figure 38 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4



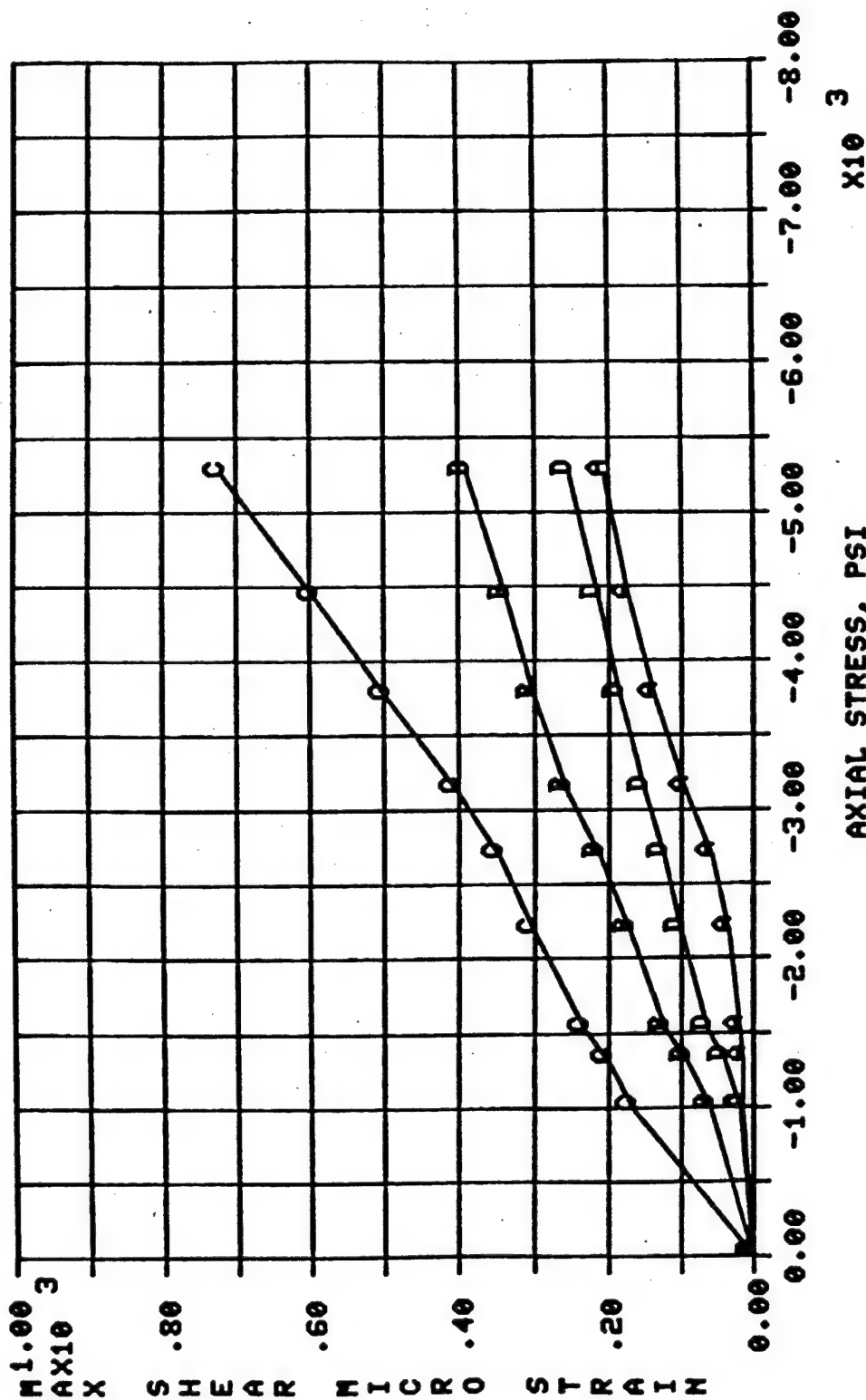


Figure 39 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

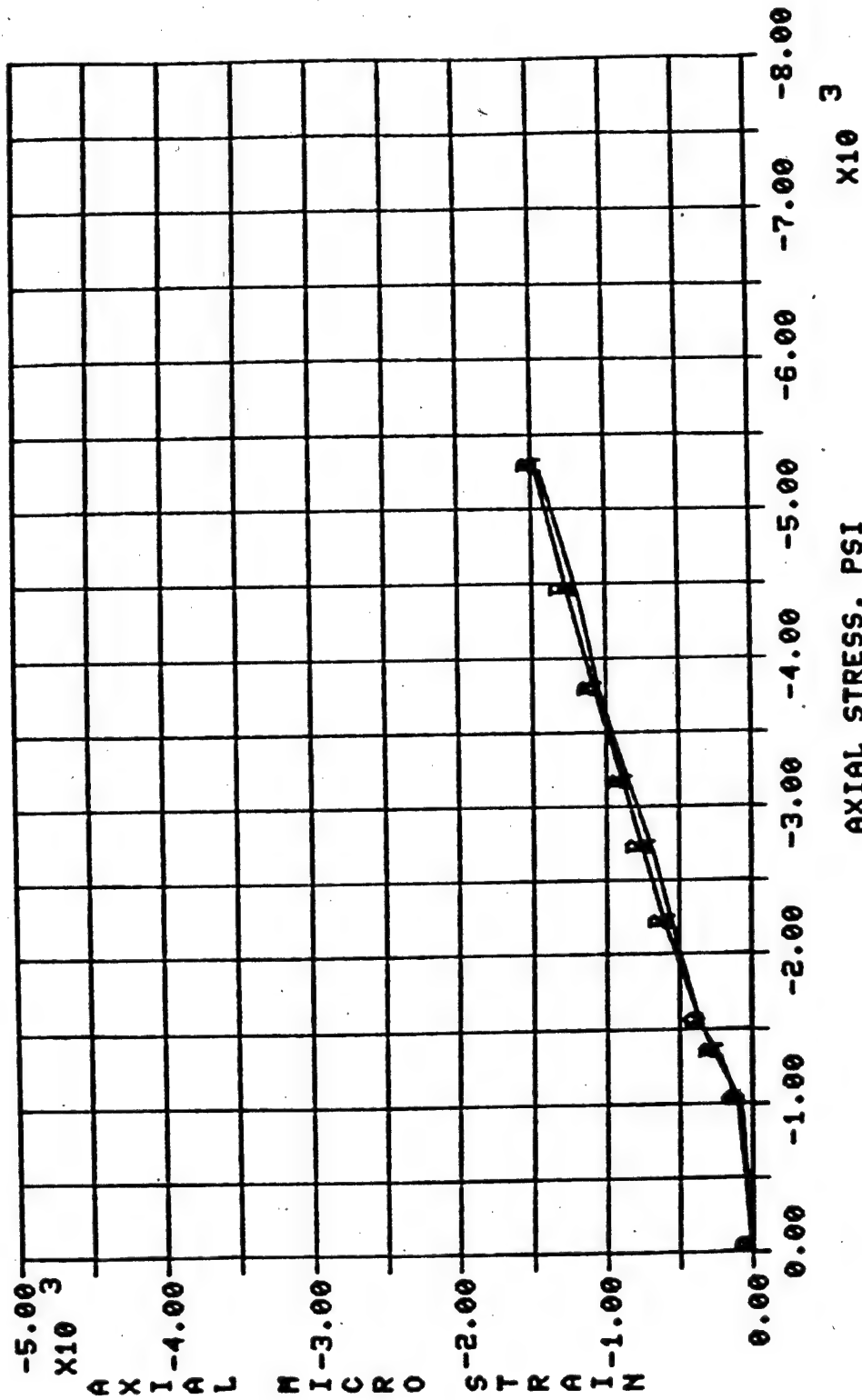


Figure 40 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

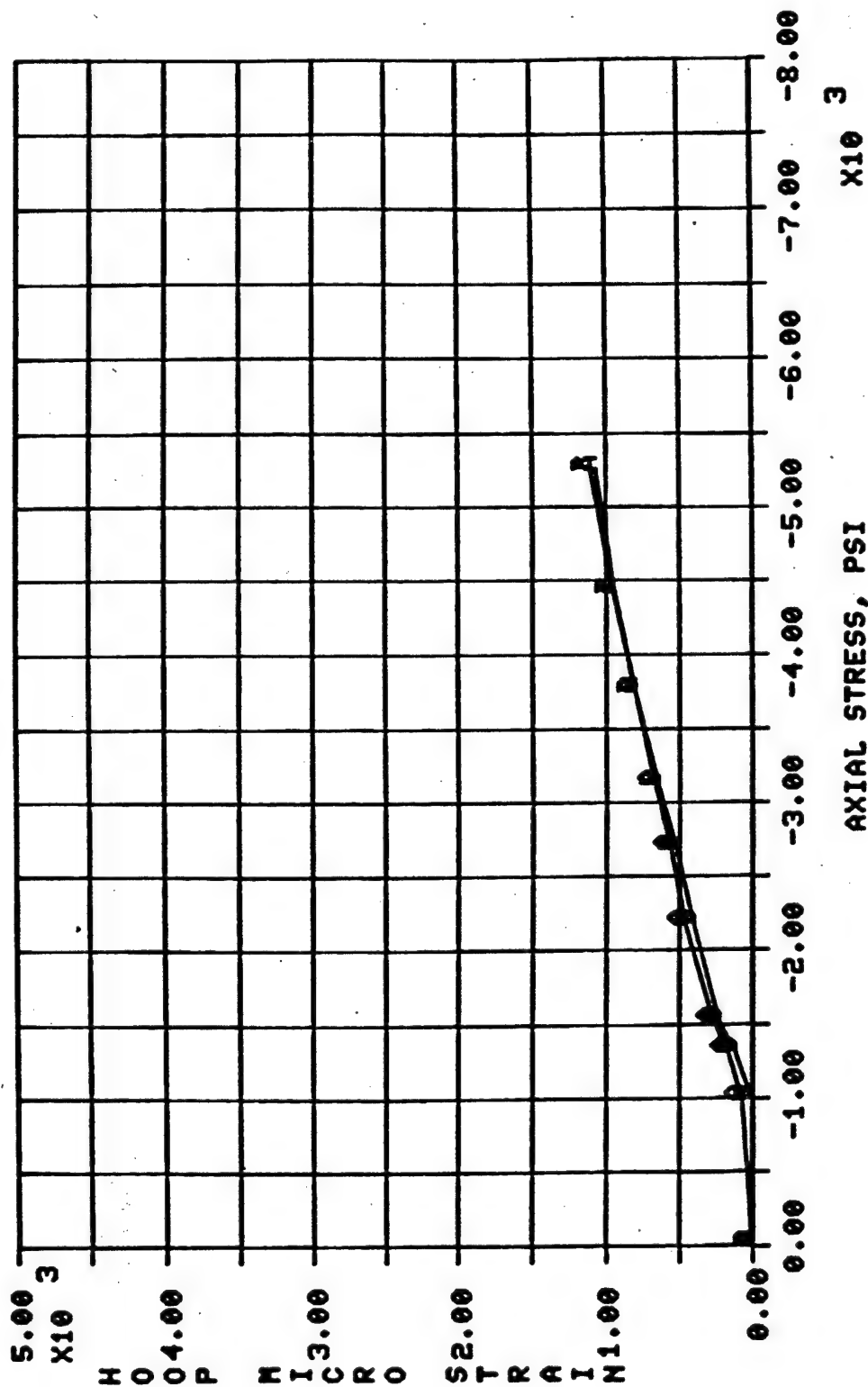


Figure 41 Test 4-A. Layup  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

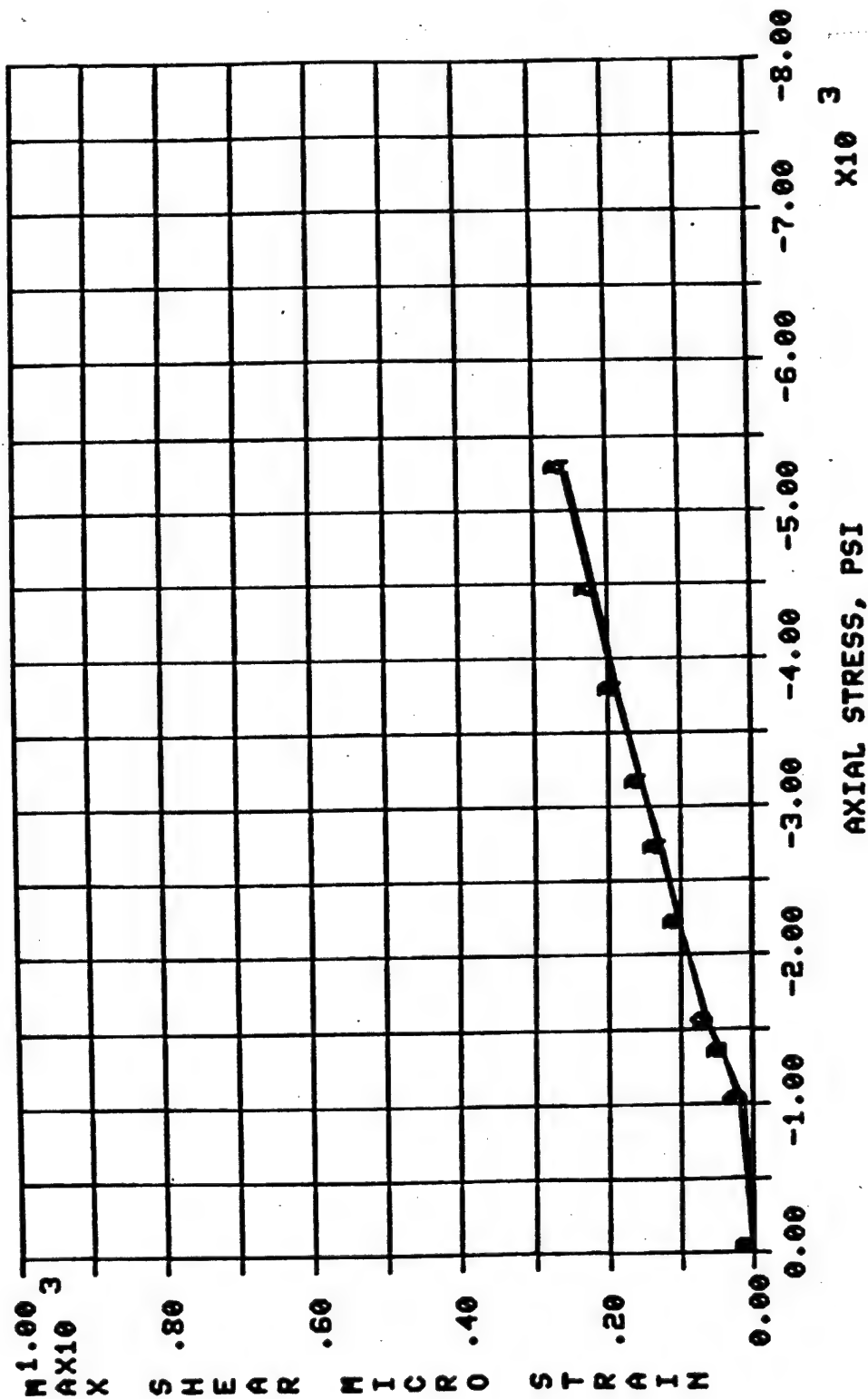


Figure 42 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

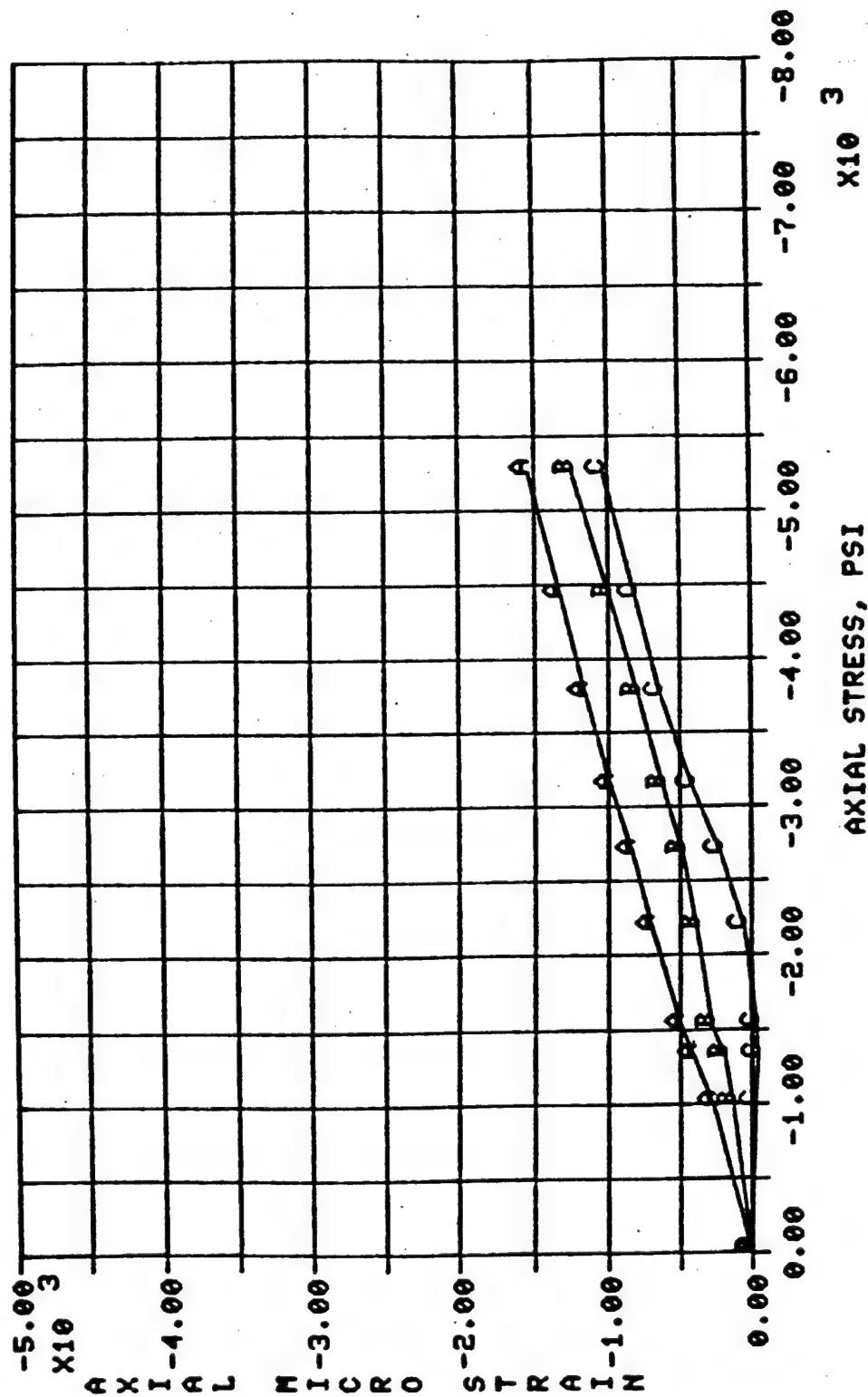


Figure 43 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Edge Rosettes

- A - Rosette No. 6
- B - Rosette No. 7
- C - Rosette No. 8

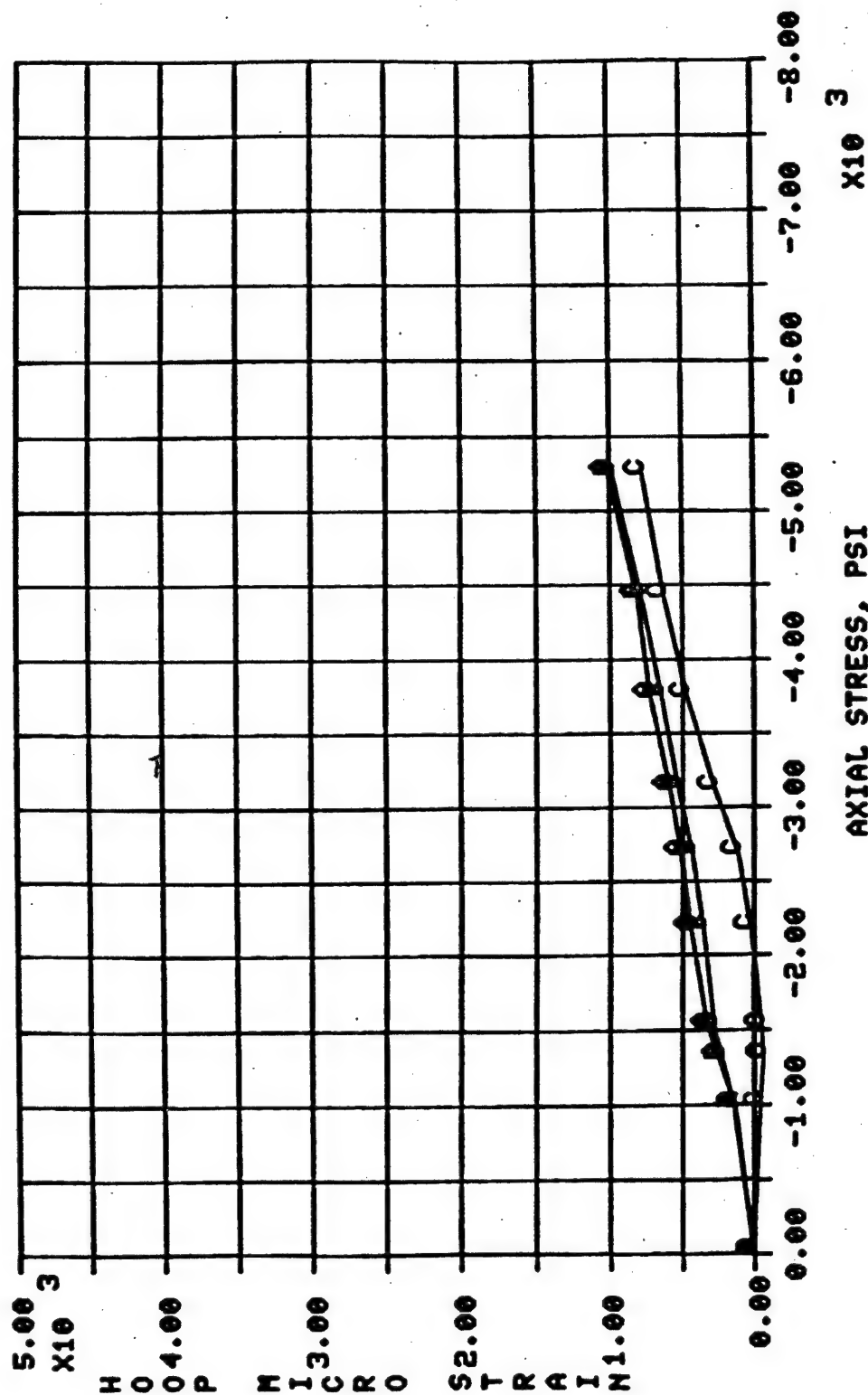


Figure 44 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Edge Rosettes

- A - Rosette No. 6
- B - Rosette No. 7
- C - Rosette No. 8

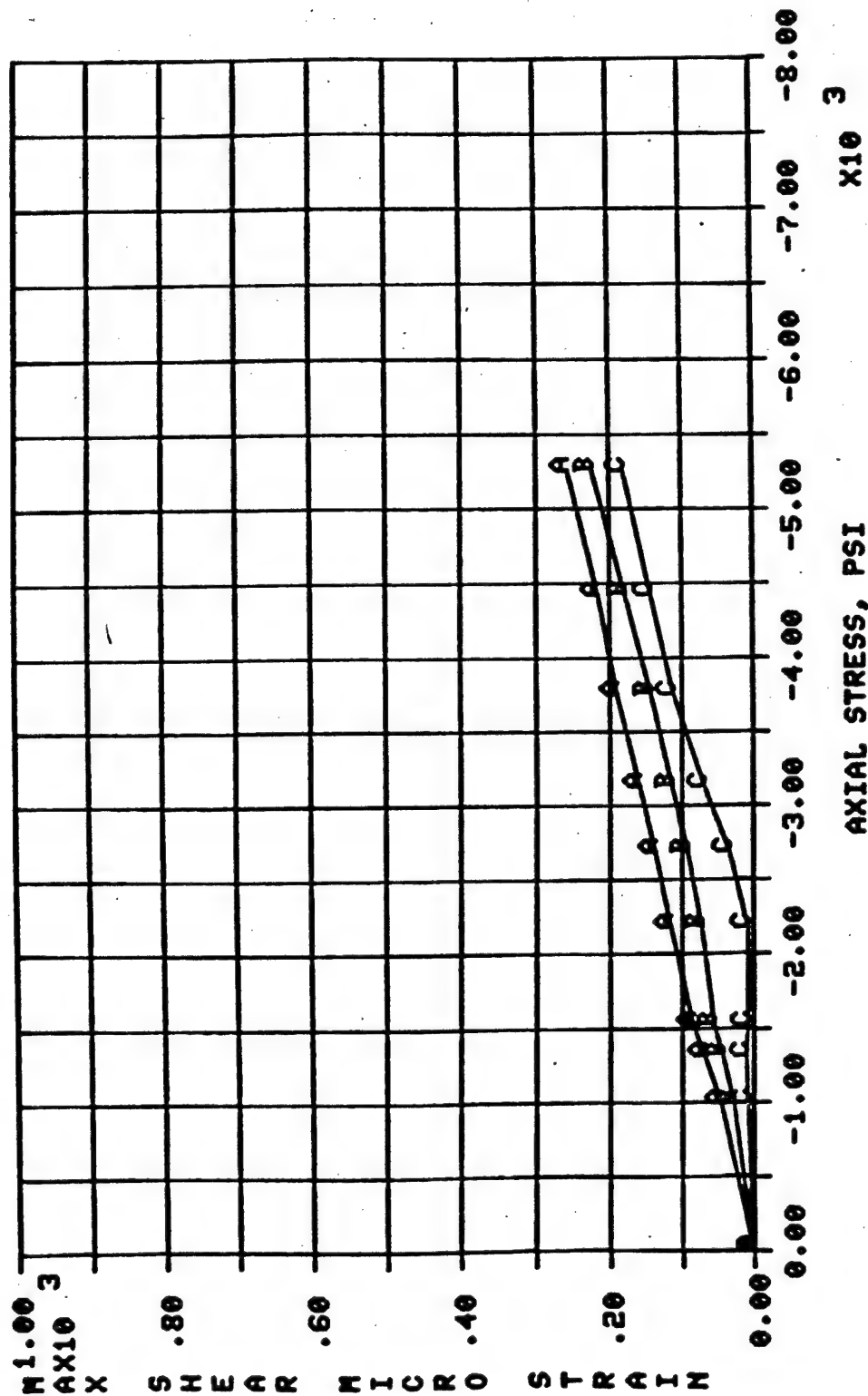


Figure 45 Test 4-A. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

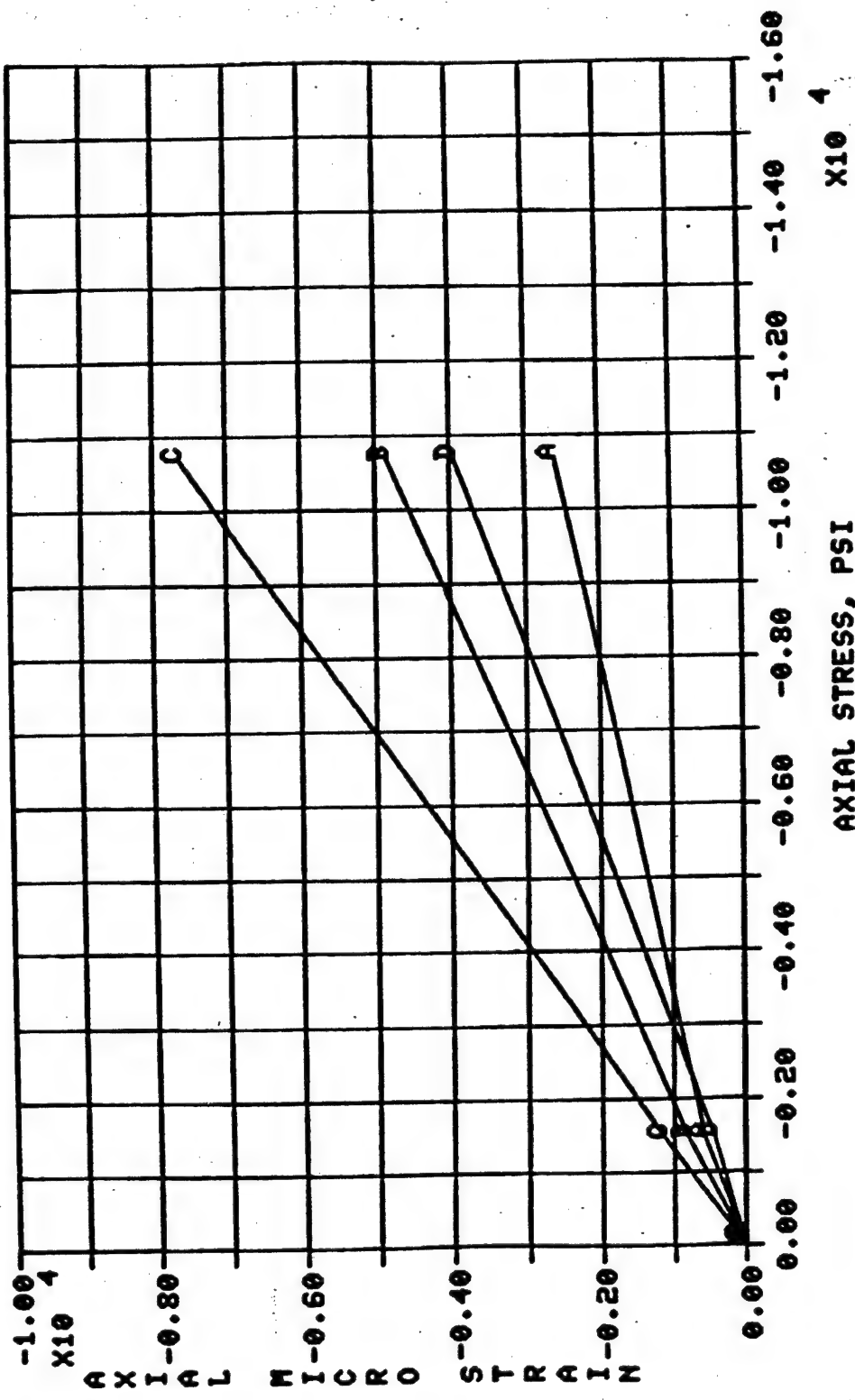


Figure 46    Test 4-B.    Layup  $\pm 45^\circ$  Axial Load Only  
Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4



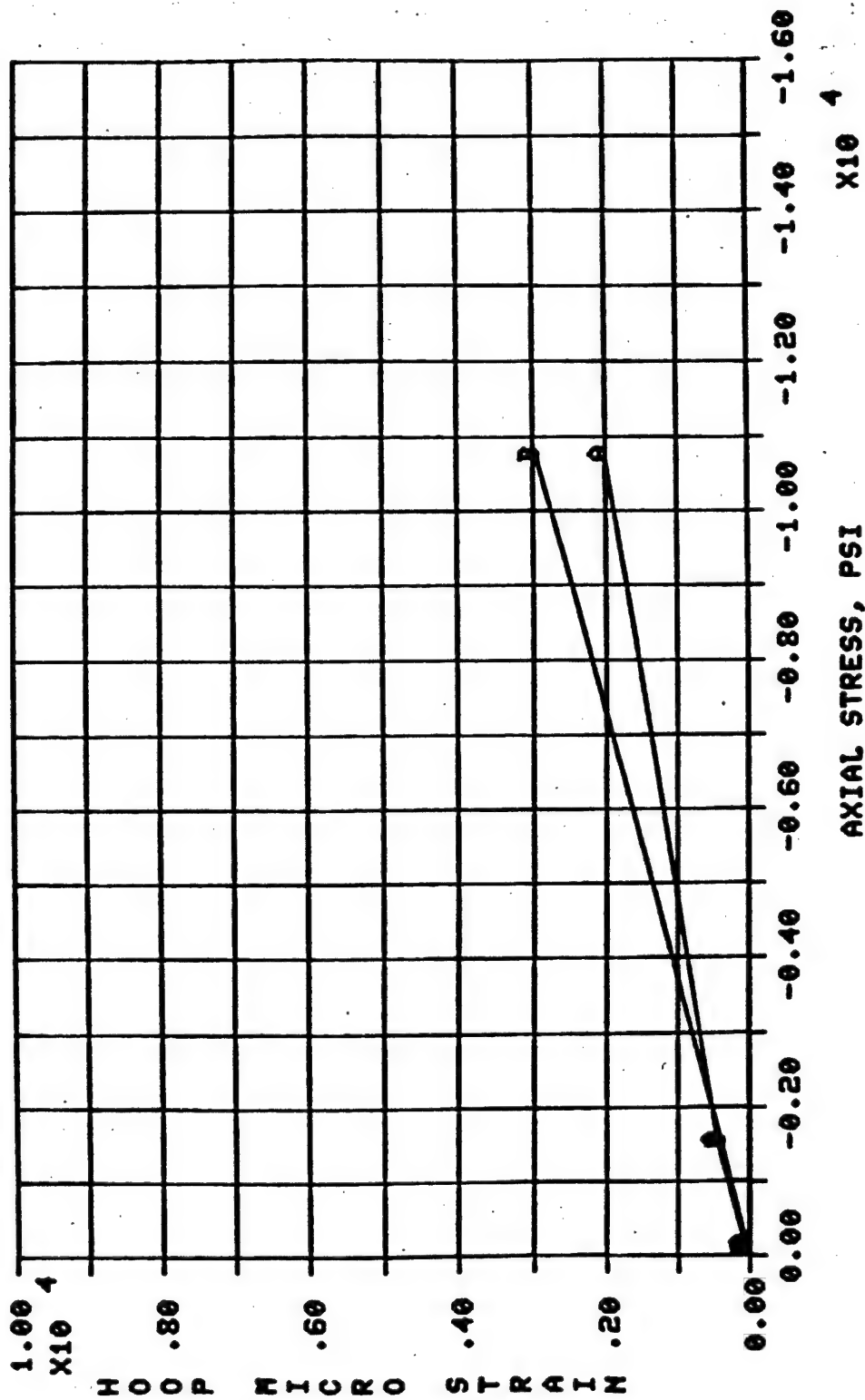


Figure 47. Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Outside Rosettes  
A - Rosette No. 1  
B - Rosette No. 4

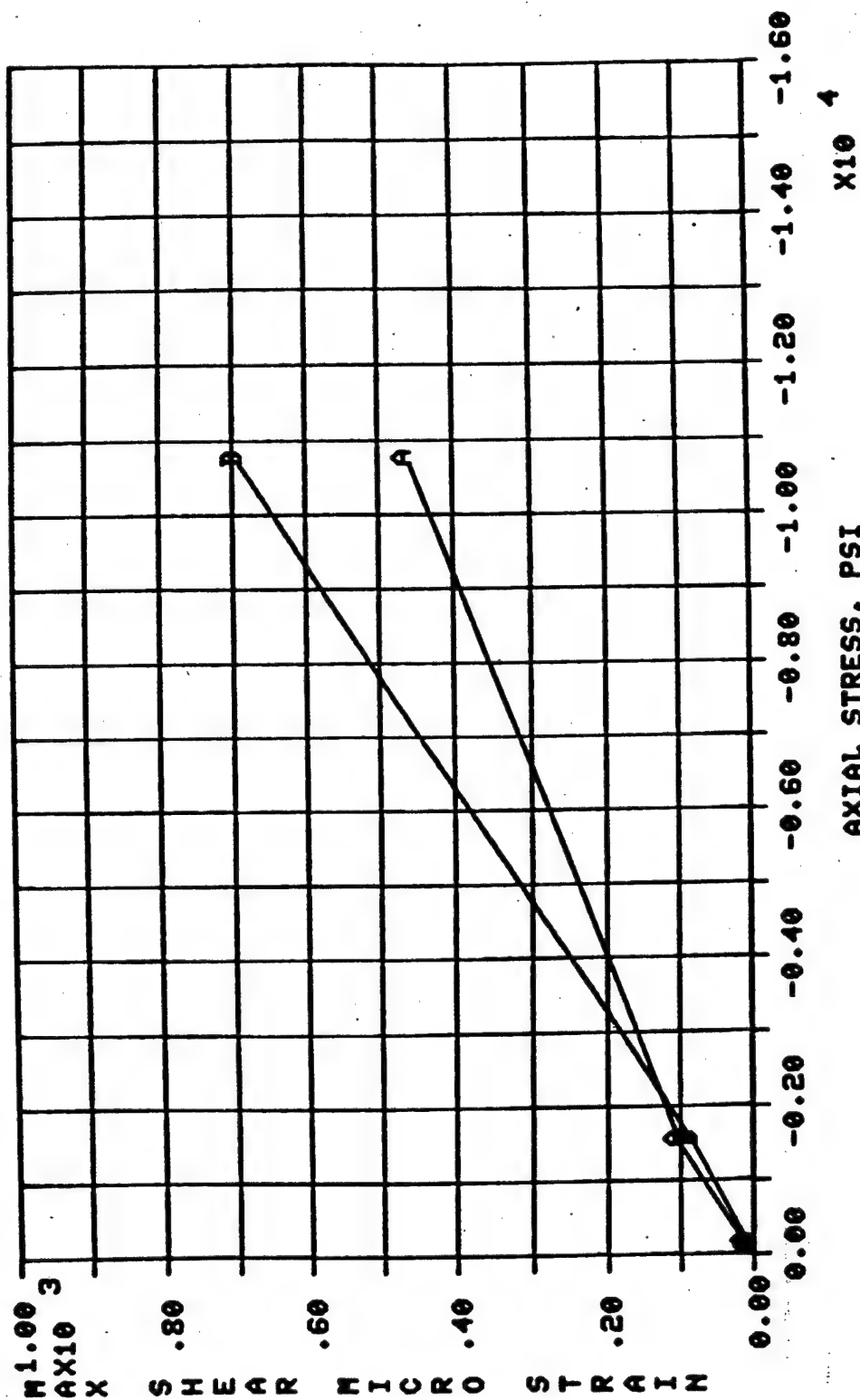


Figure 48 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Outside Rosettes  
A - Rosette No. 1  
B - Rosette No. 4

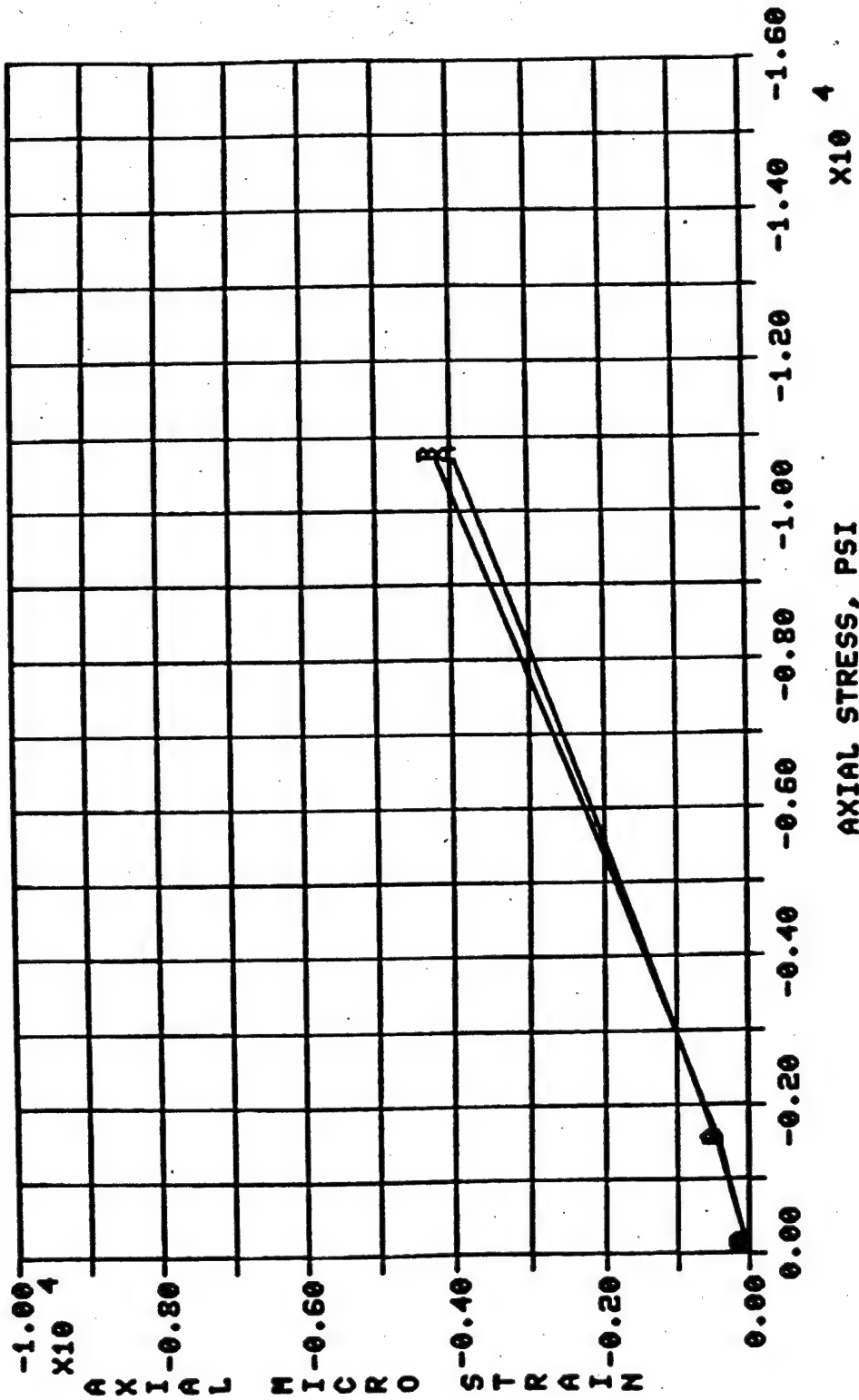


Figure 49 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

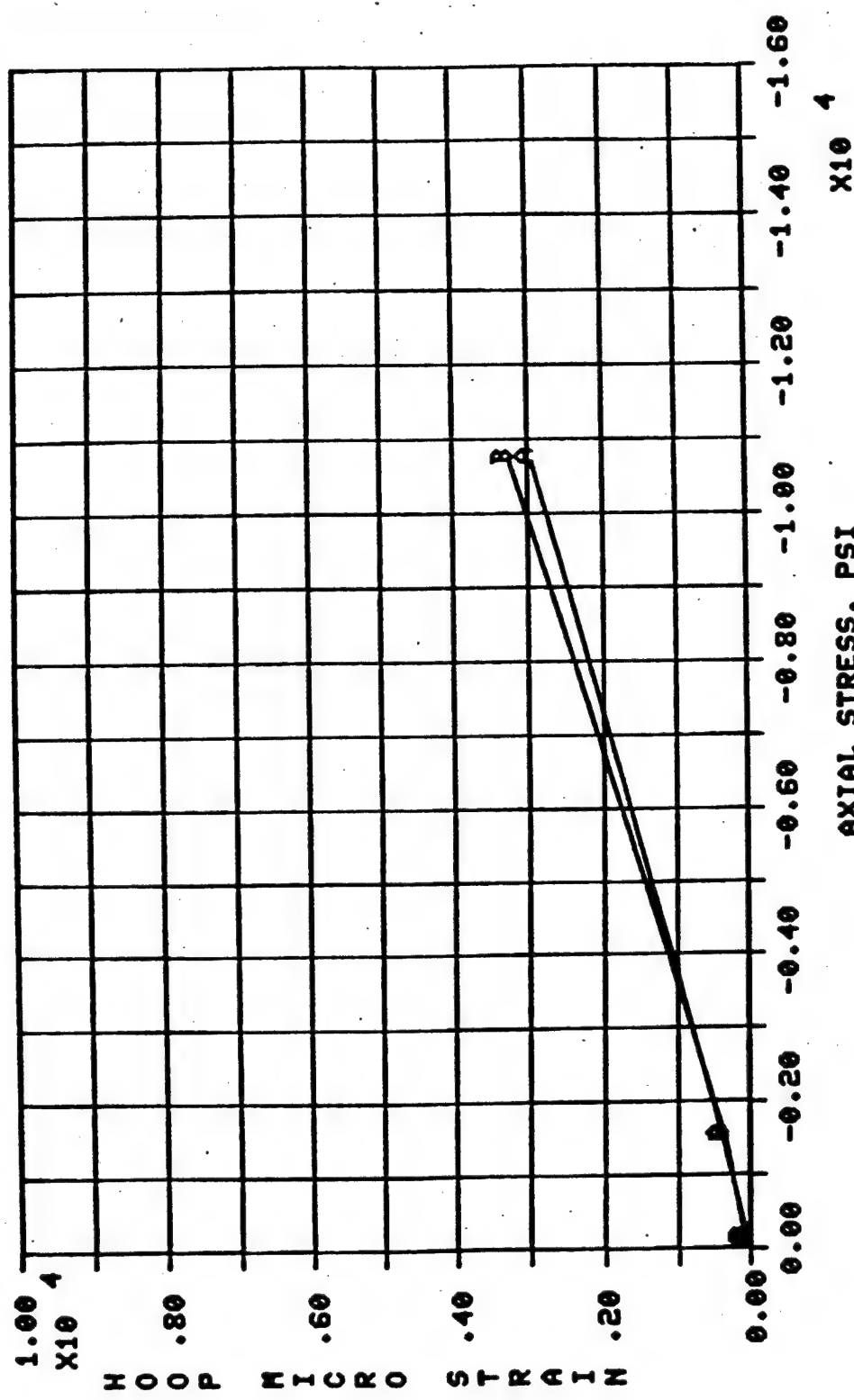


Figure 50 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

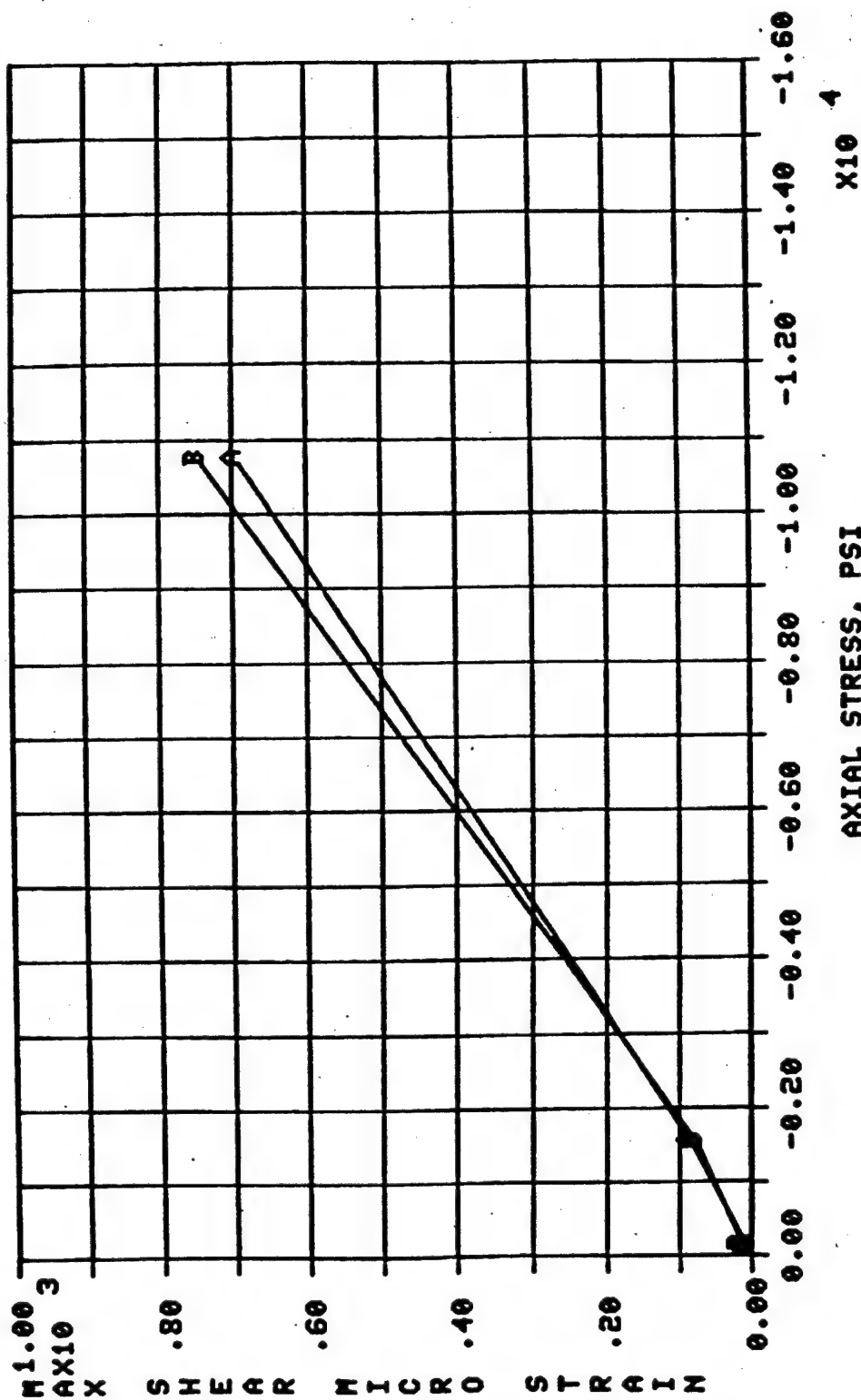


Figure 51 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Inside/Outside Rosettes  
A - Rosette No. 4  
B - Rosette No. 5 (inside)

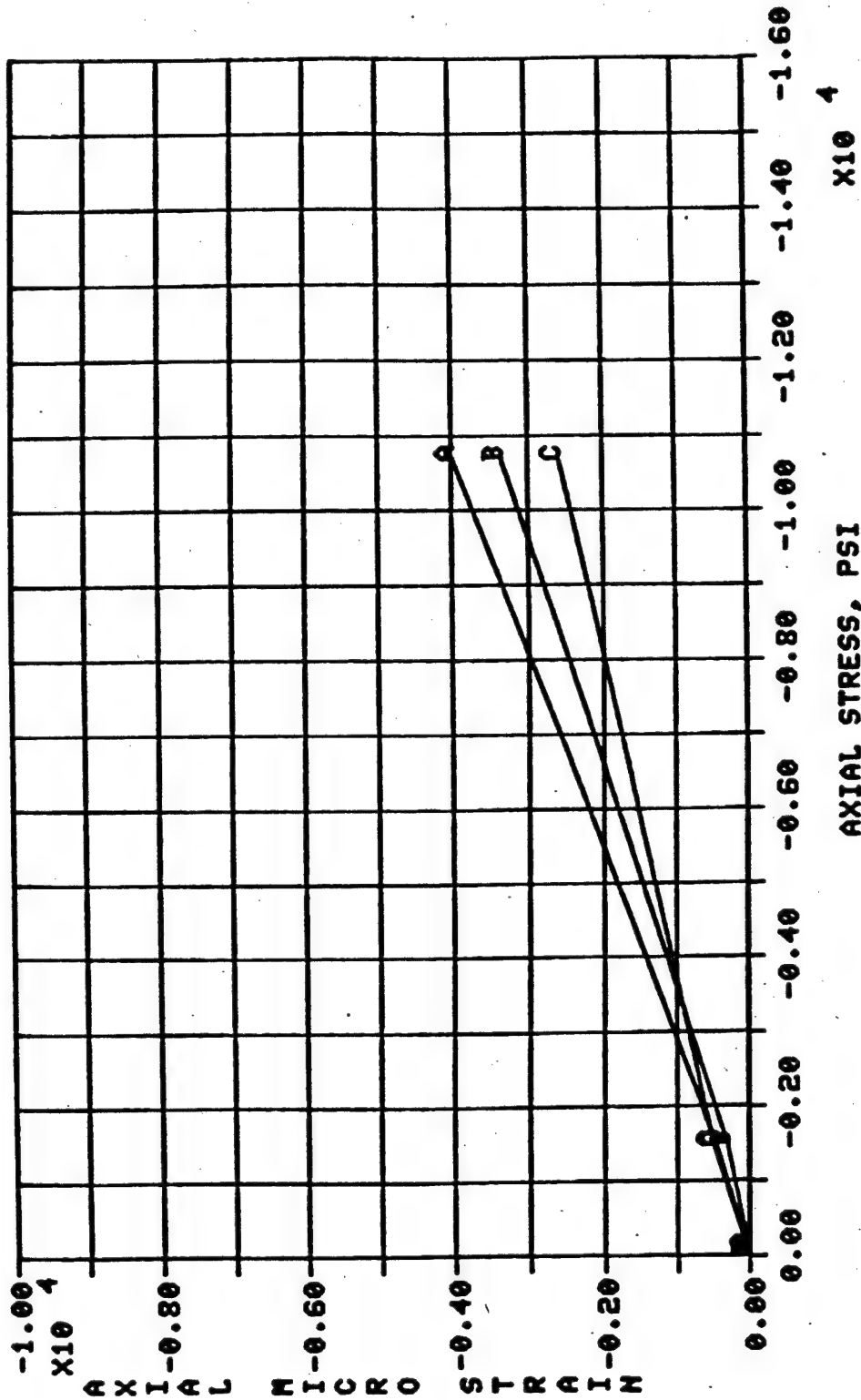


Figure 52 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

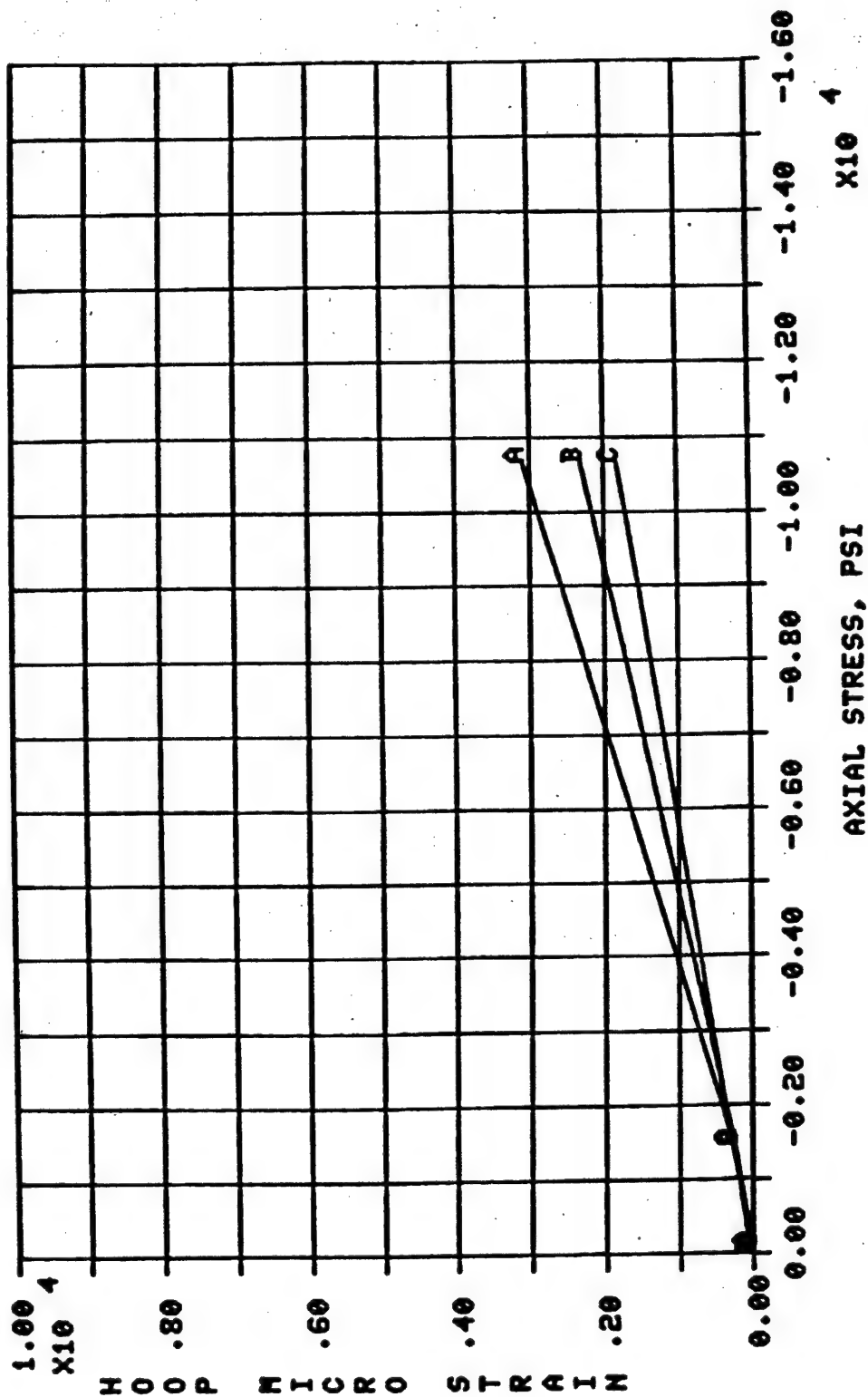


Figure 53 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

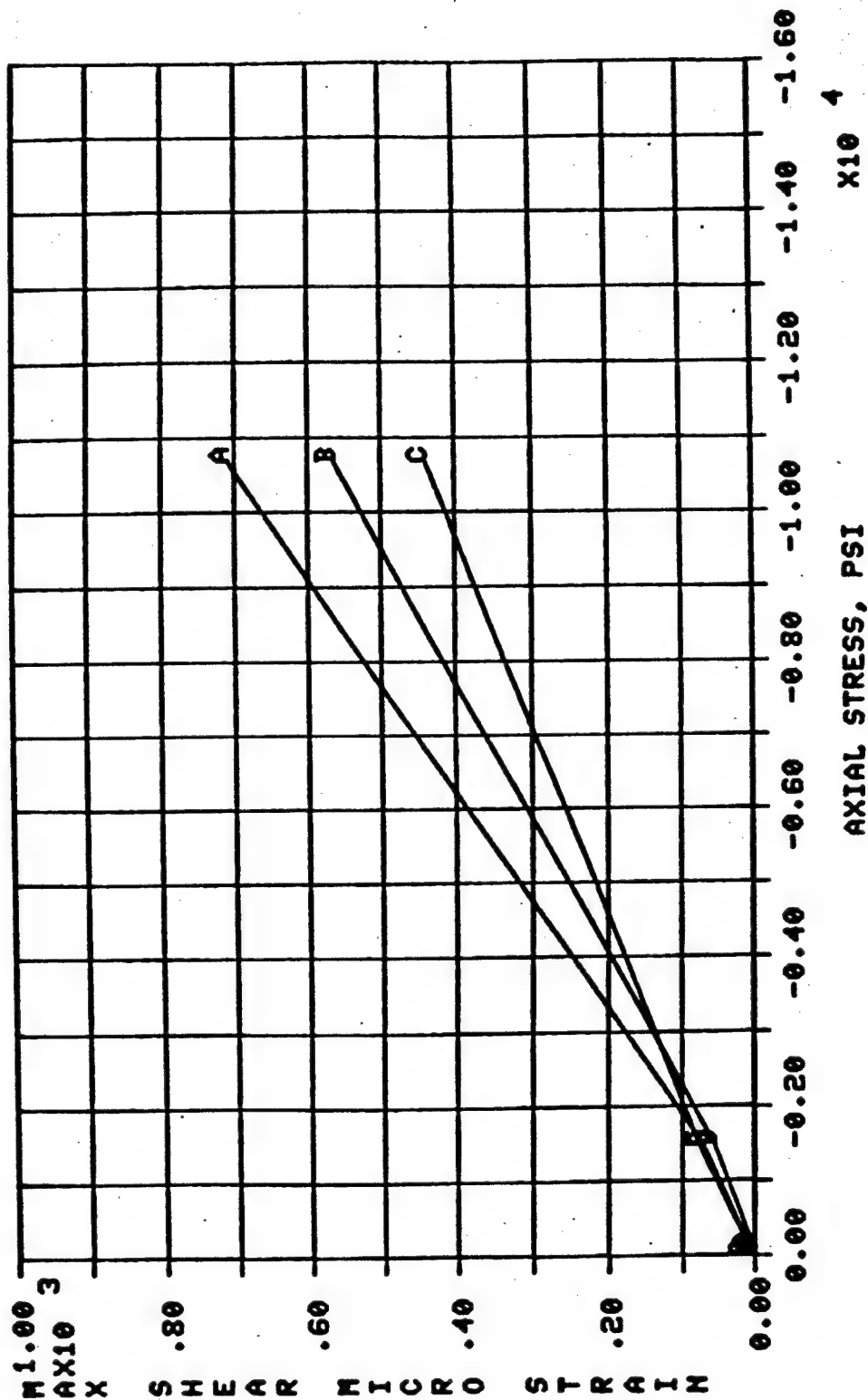


Figure 54 Test 4-B. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8



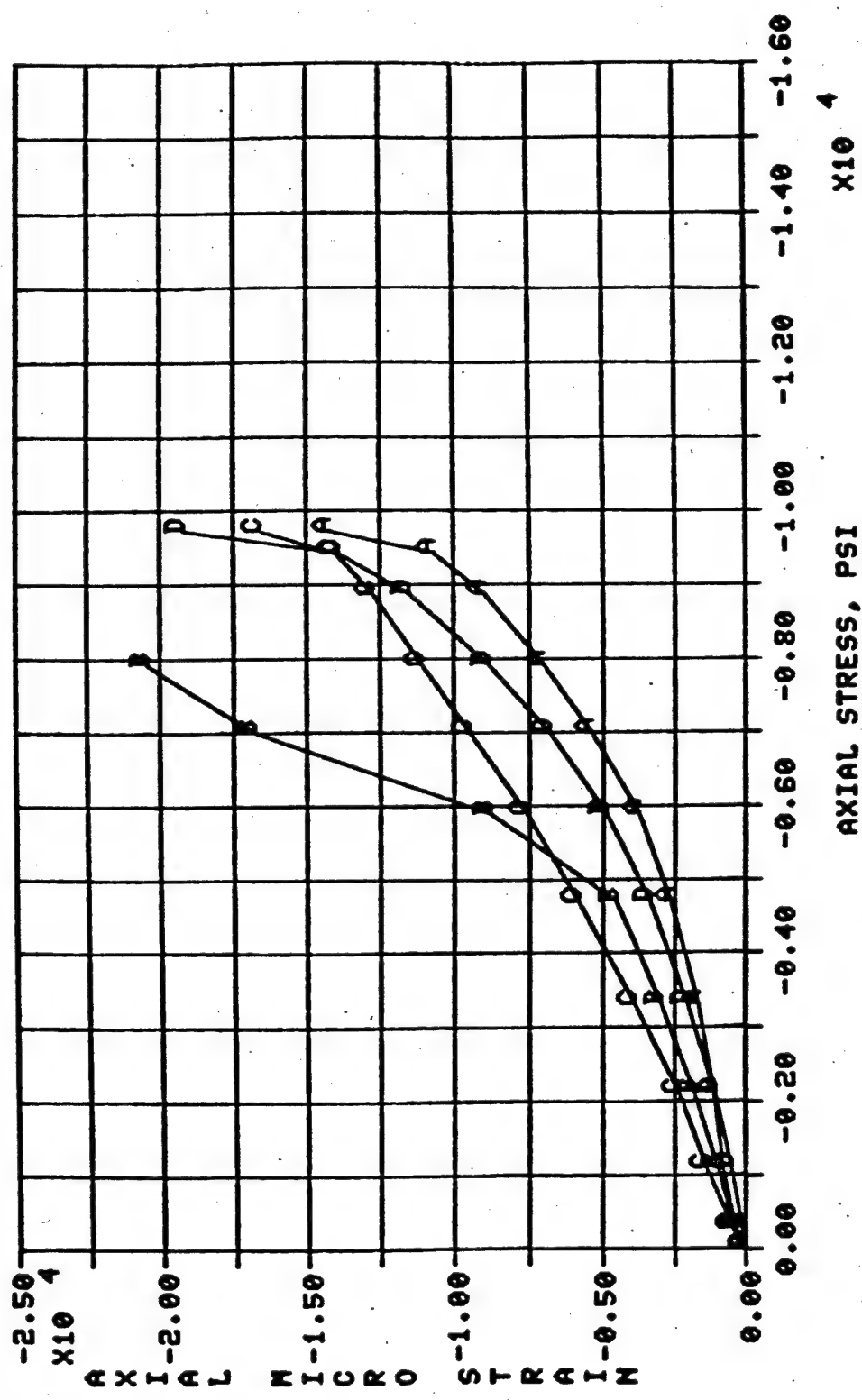


Figure 55 Test 4-C. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4

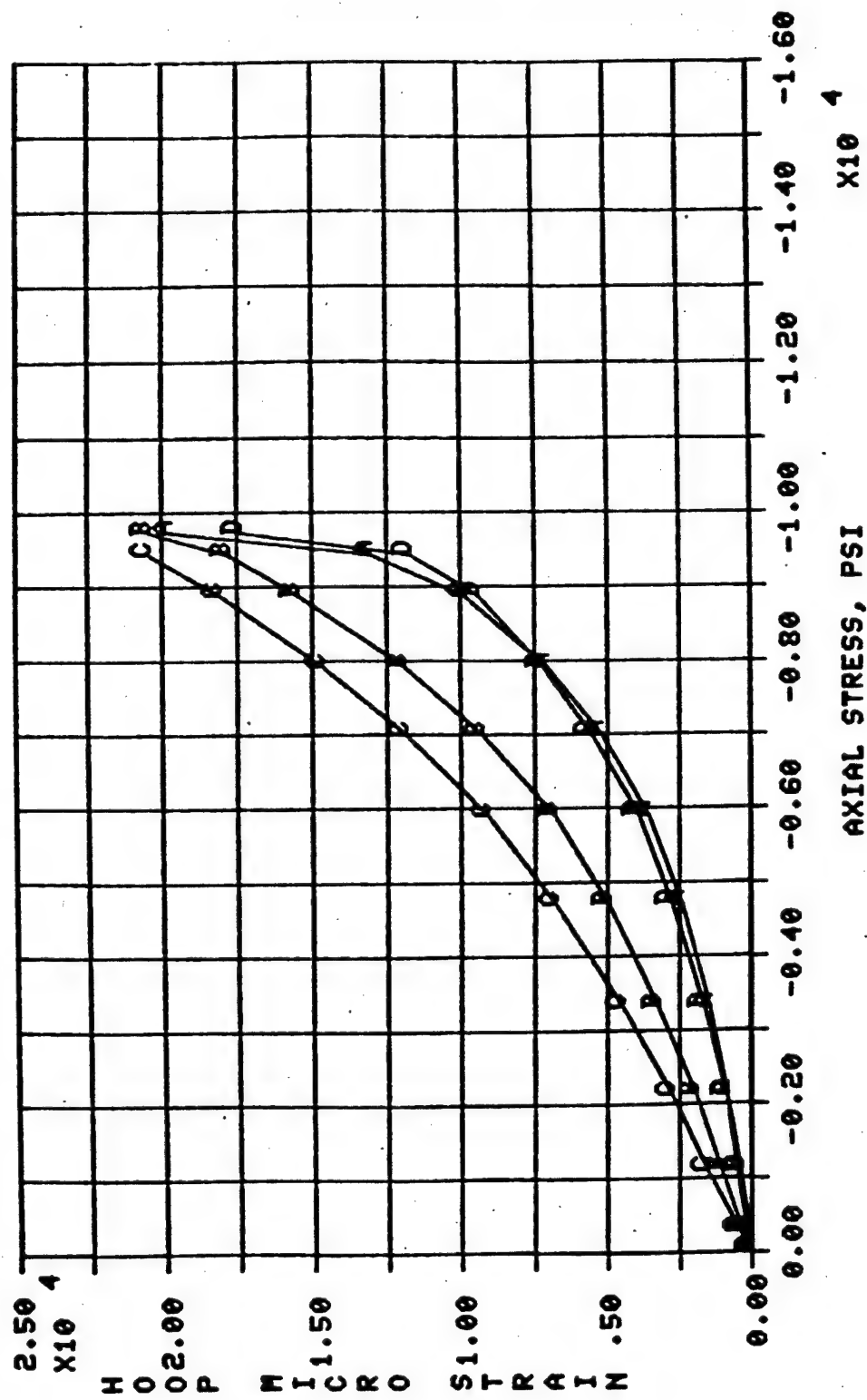


Figure 56 Test 4-C. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

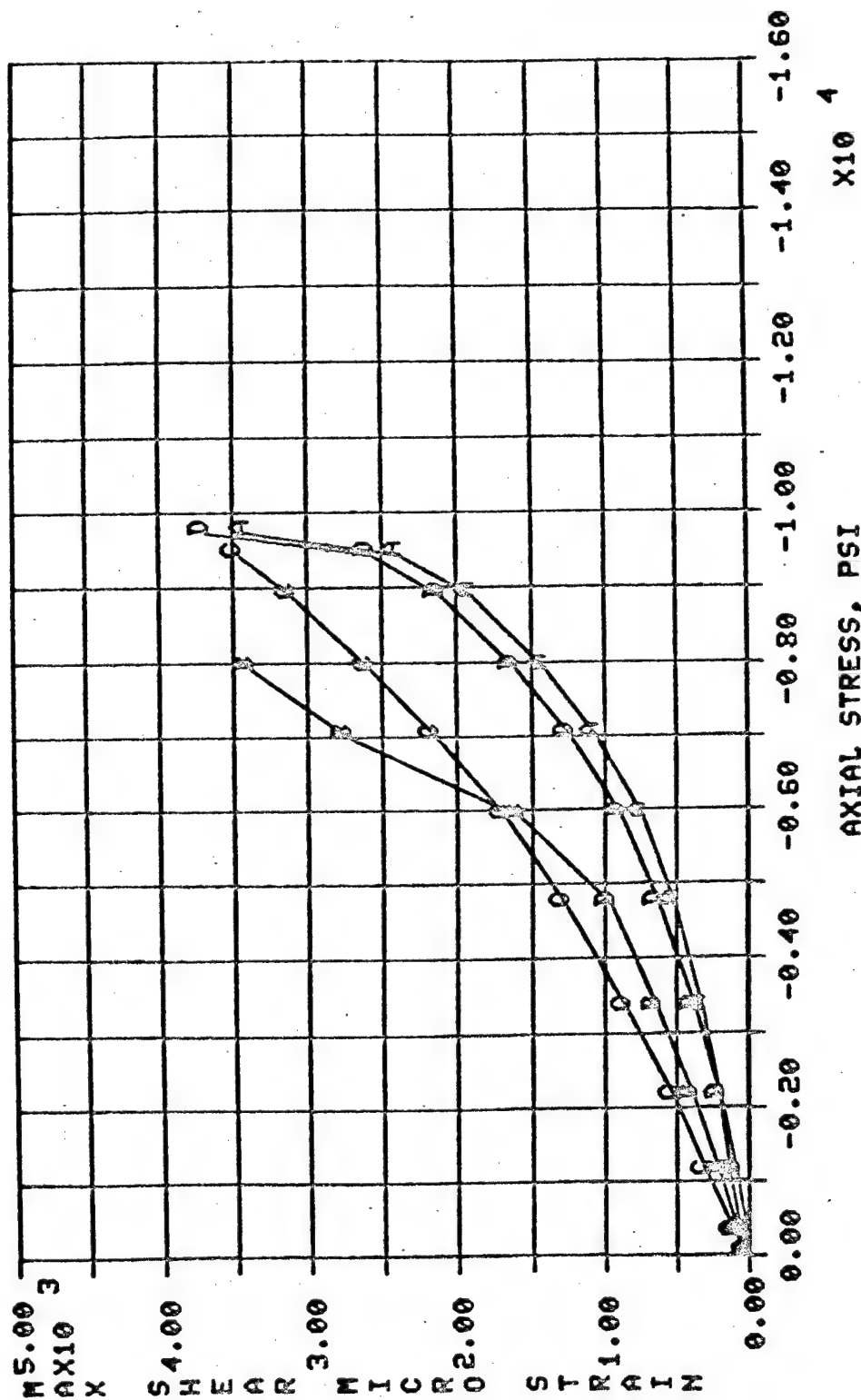


Figure 57 Test 4-C. Layout #45 Axial Load Only  
Max. Shear Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

surface of the specimen for Test 4-C. Strains at Locations 1 and 4 are in good agreement. Figures 58, 59 and 60 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the inside/outside comparison gages. Here good agreement is shown, indicating very little bending is occurring. Figures 61, 62 and 63 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the edge rosettes. Fairly good agreement is shown, much better than the gages located at the center of the specimen showed.

If the results of Tests 4-A, 4-B and 4-C are plotted together, such as in Figures 64 through 67, an interesting point comes to light. From these figures, one sees that Test 4-A and Test 4-B give almost identical results, while Test 4-C produced much higher strains. Also, note that the axial stress of Test 4-B is higher than that of Test 4-C. It is thought that Test 4-B damaged the specimen (internal breakage of fibers), and this could account for the behavior of Test 4-C.

For Test 5, external pressure was applied to the same specimen as used in Tests 4-A, 4-B and 4-C. Figures 68, 69 and 70 present the axial, hoop and maximum shear strains, respectively, for two rosettes located on the inside surface, one at the center and one at the edge. Both rosettes are located at the same angular location. The results are in very poor agreement. This could be because the specimen was damaged in Test 4, as discussed above, or because buckling was taking place. Fracture of the specimen, shown in Figure 71, was from ply delamination and hoop direction blooming.

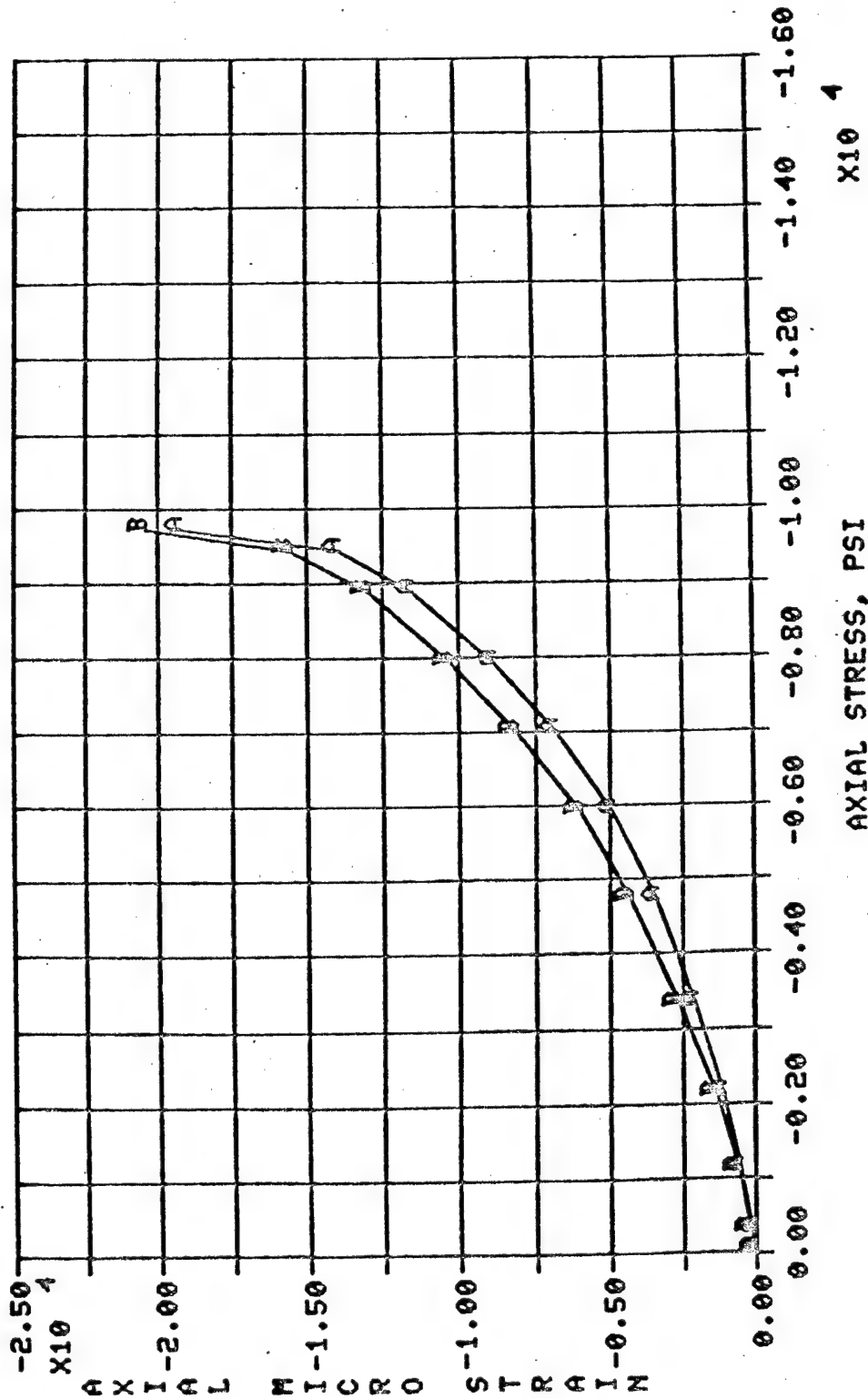


Figure 58 Test 4-C Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

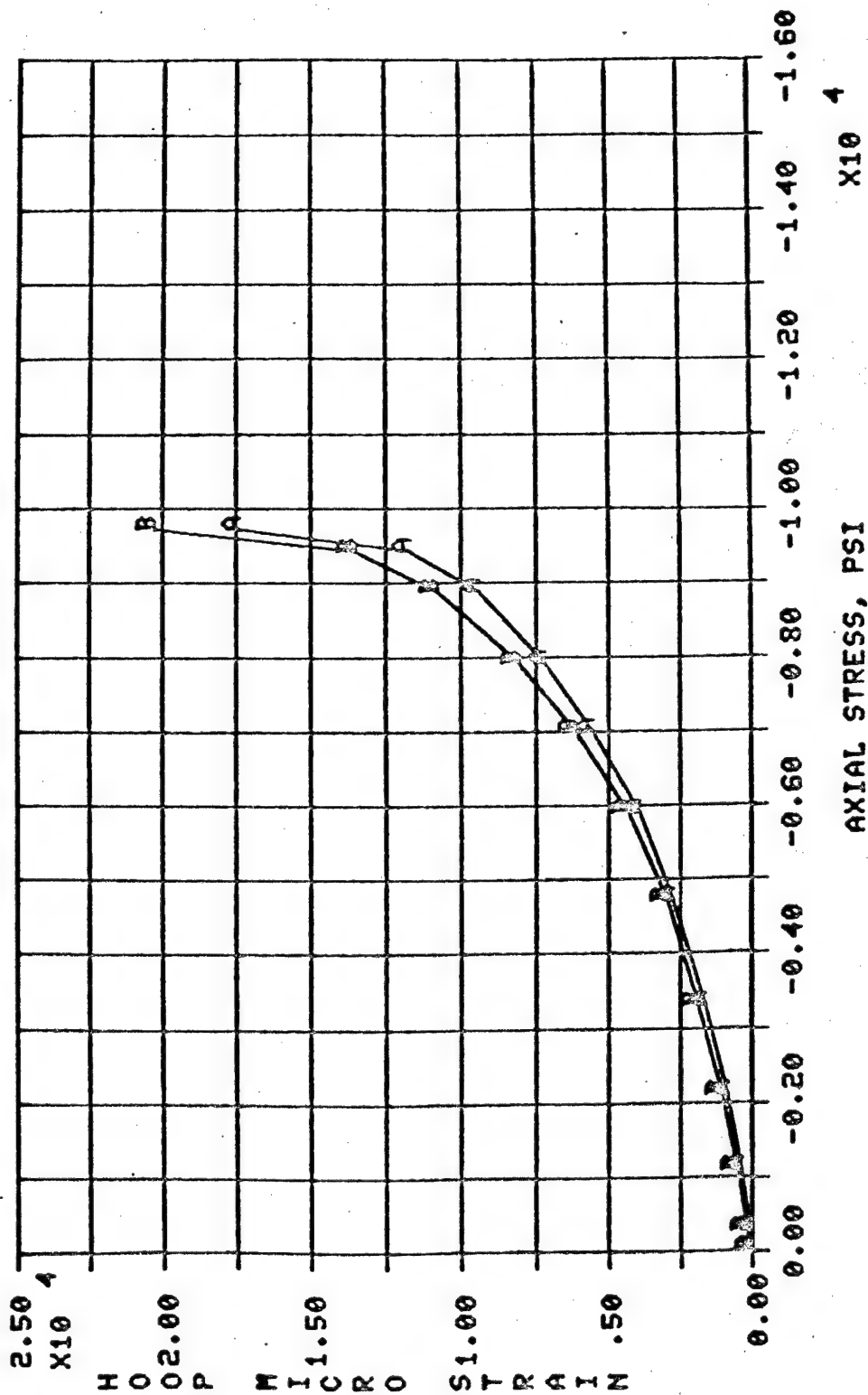


Figure 59 Test 4-C. Layup  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

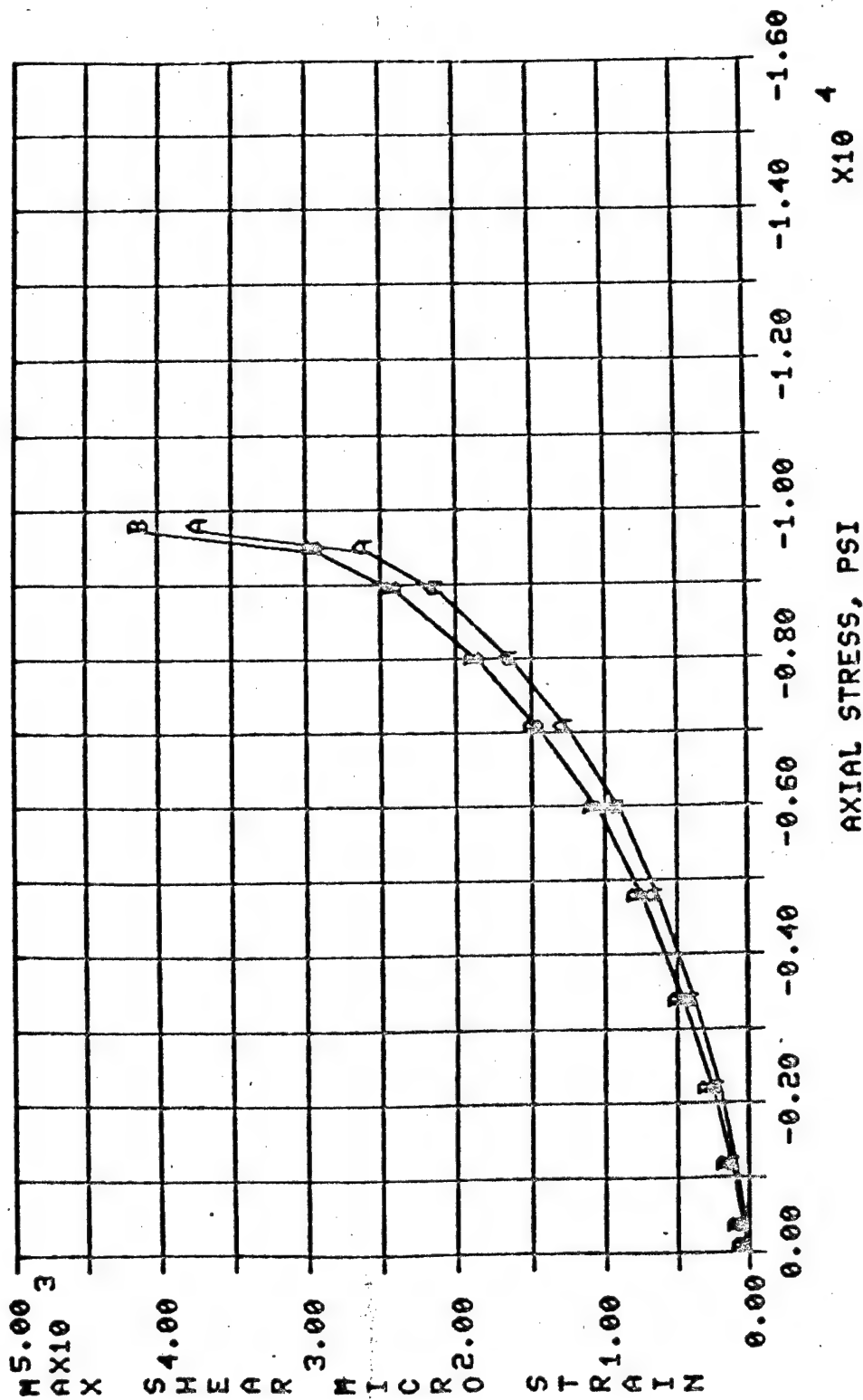


Figure 60 Test 4-C. Layup  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

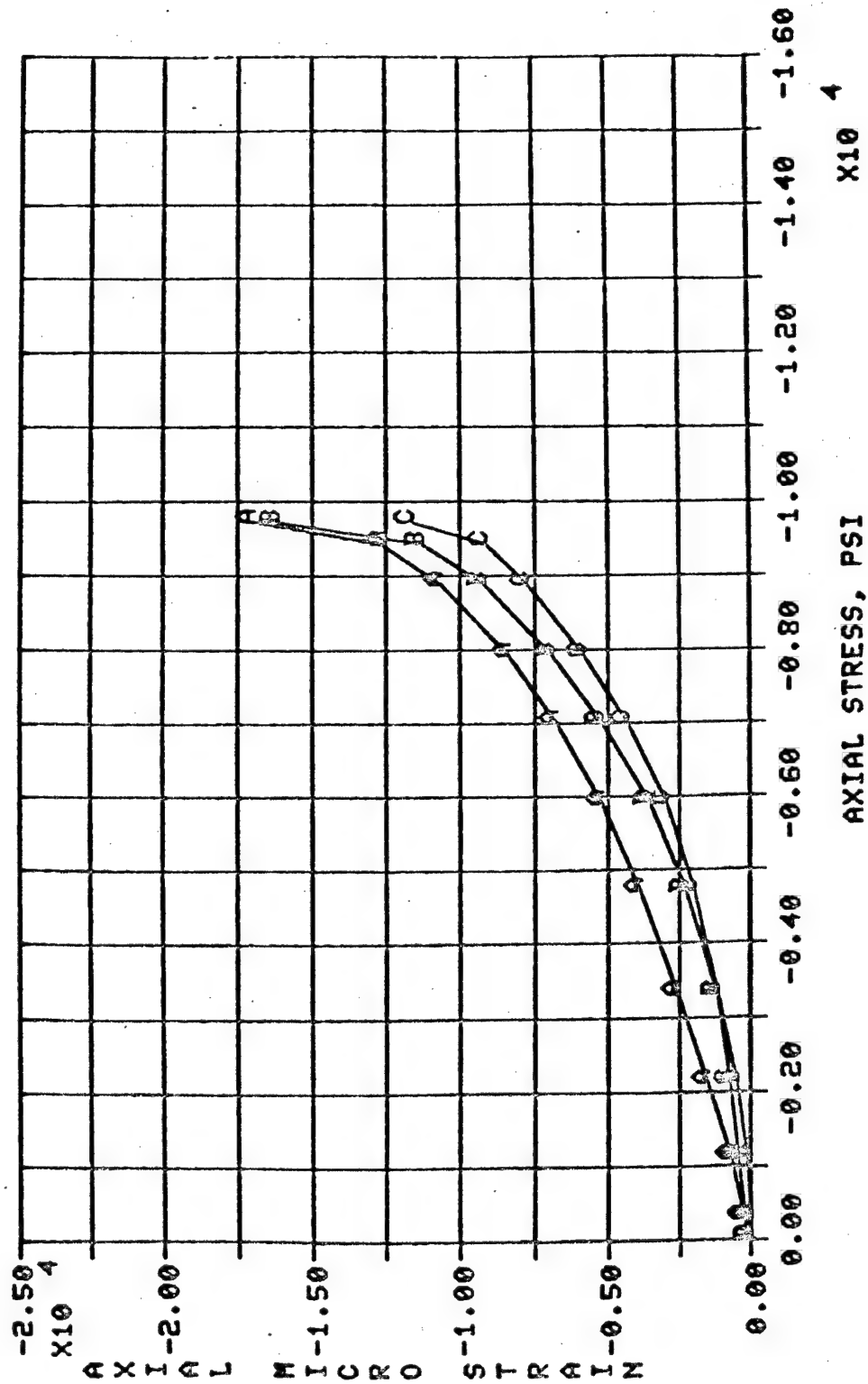


Figure 61 Test 4-C. Layout  $\pm 45^\circ$  Axial Load Only  
Axial Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8



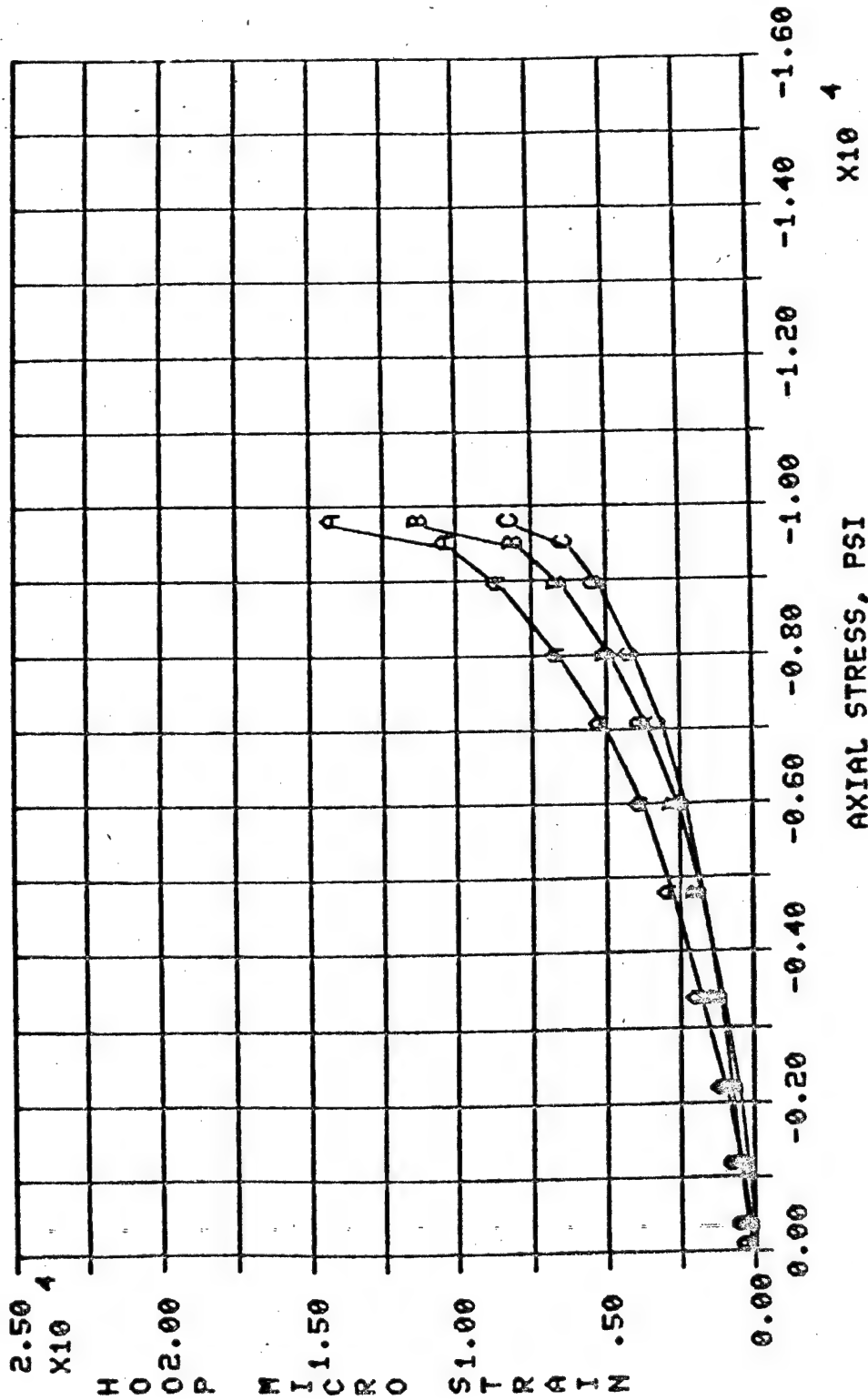


Figure 62 Test 4-C. Layout  $\pm 45^\circ$  Axial Load Only  
Hoop Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

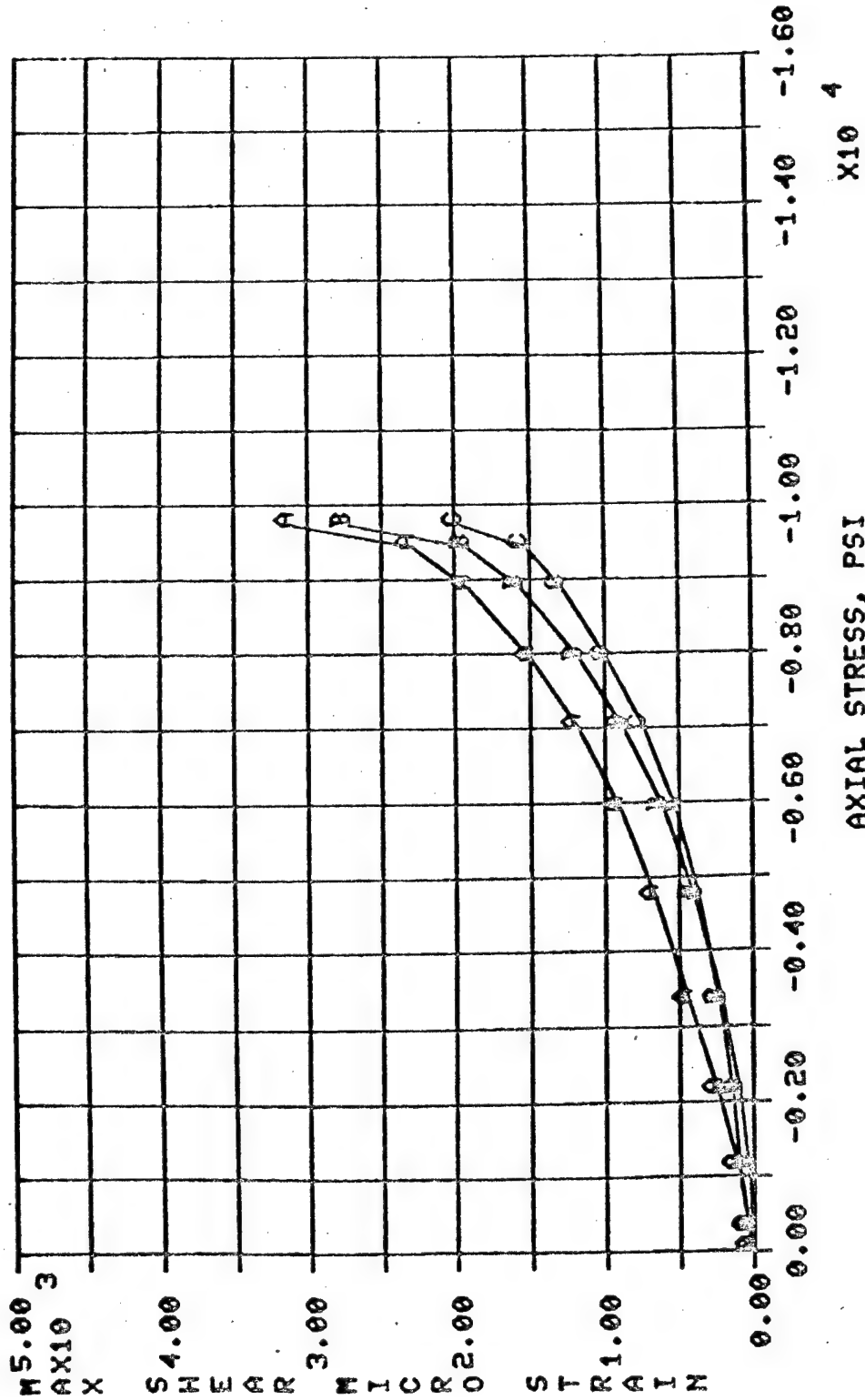


Figure 63 Test 4-C. Layout  $\pm 45^\circ$  Axial Load Only  
Max. Shear, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

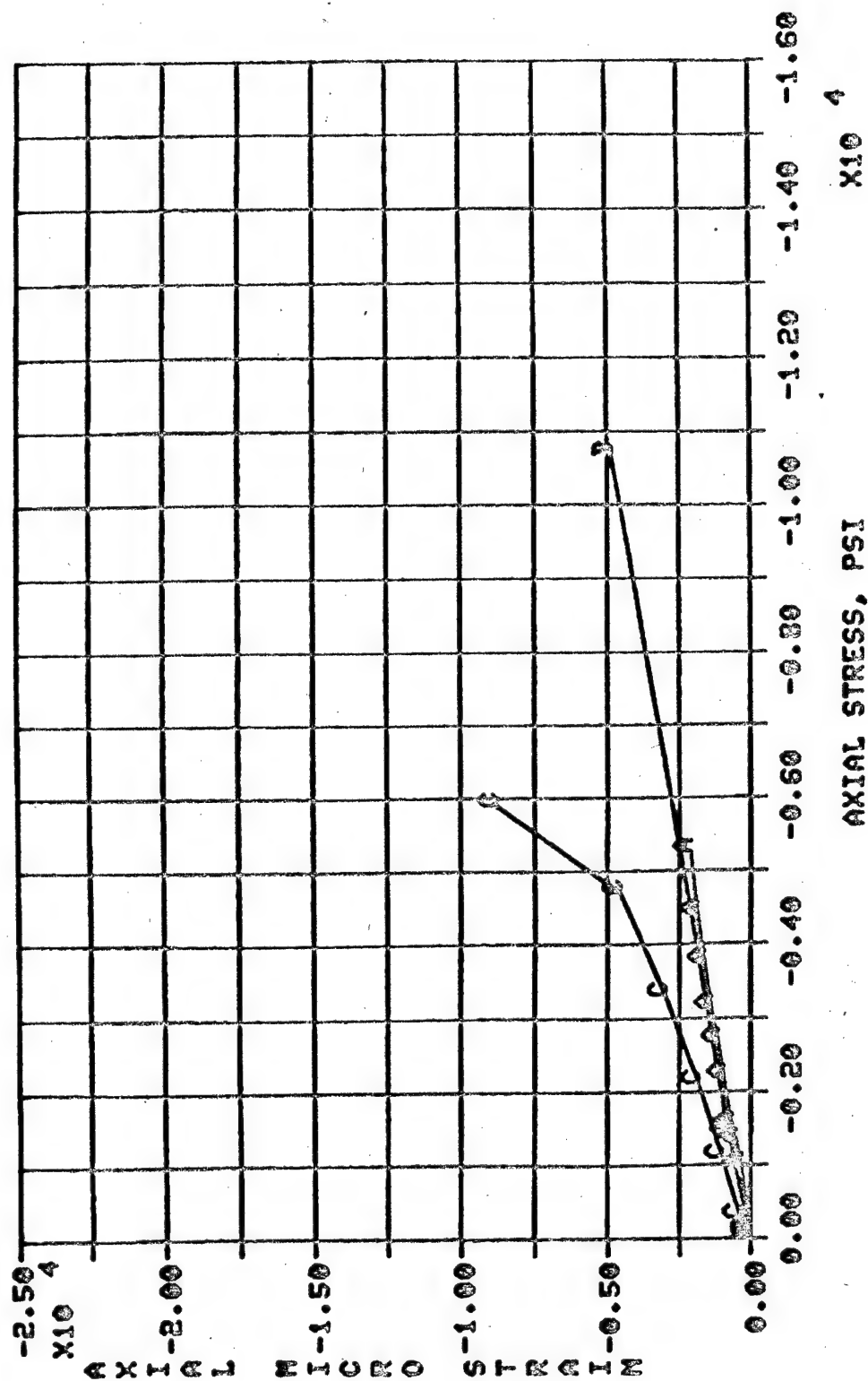


Figure 64 Tests 4-A, B, C. Layout  $\pm 45^\circ$  Axial Only  
Axial Response, Rosette No. 2

A - Test 4-A  
B - Test 4-B  
C - Test 4-C

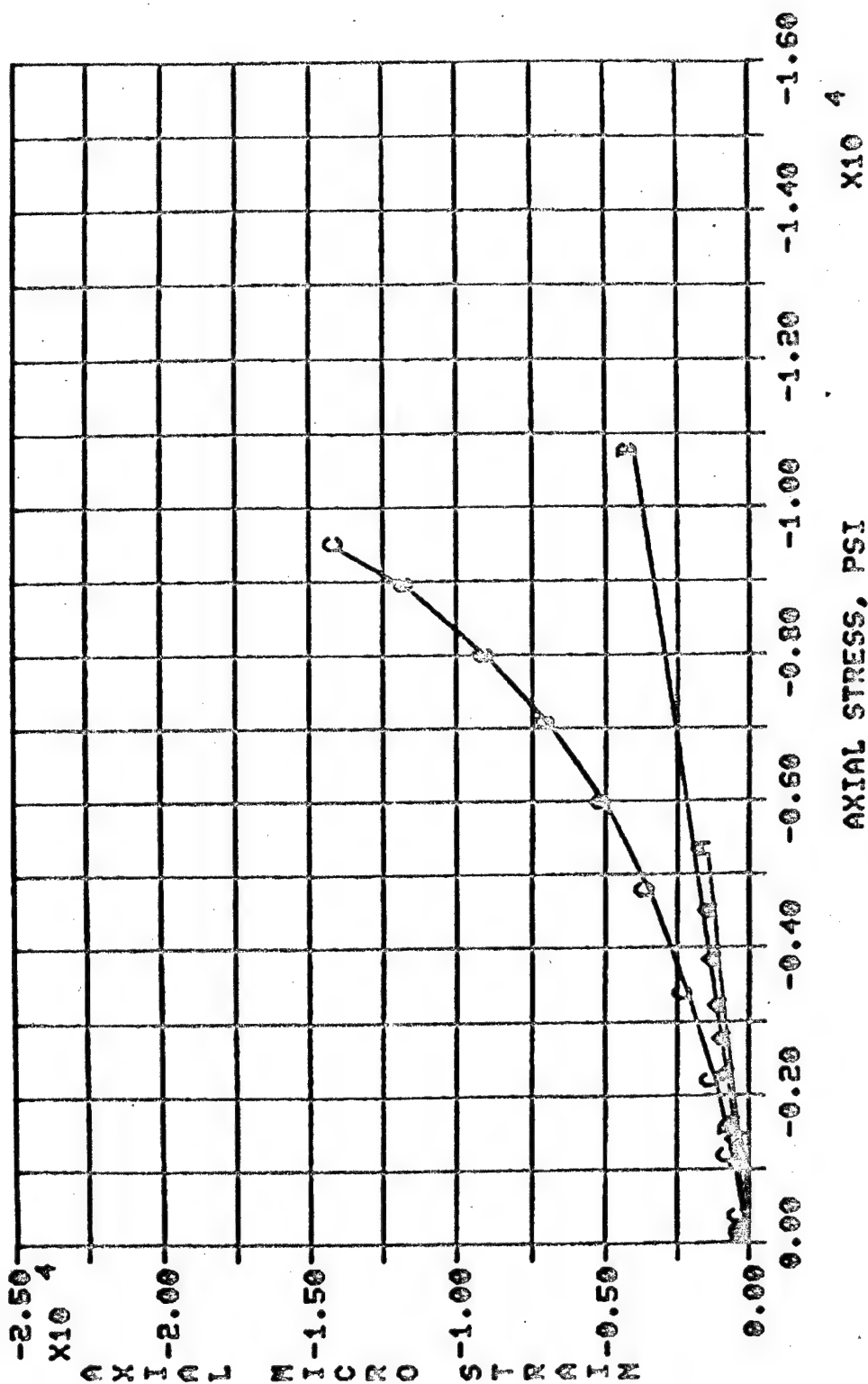


Figure 65 Tests 4-A, B, C. Layout  $\pm 45^\circ$  Axial Only  
Axial Response, Rosette No. 4

A - Test 4-A  
B - Test 4-B  
C - Test 4-C

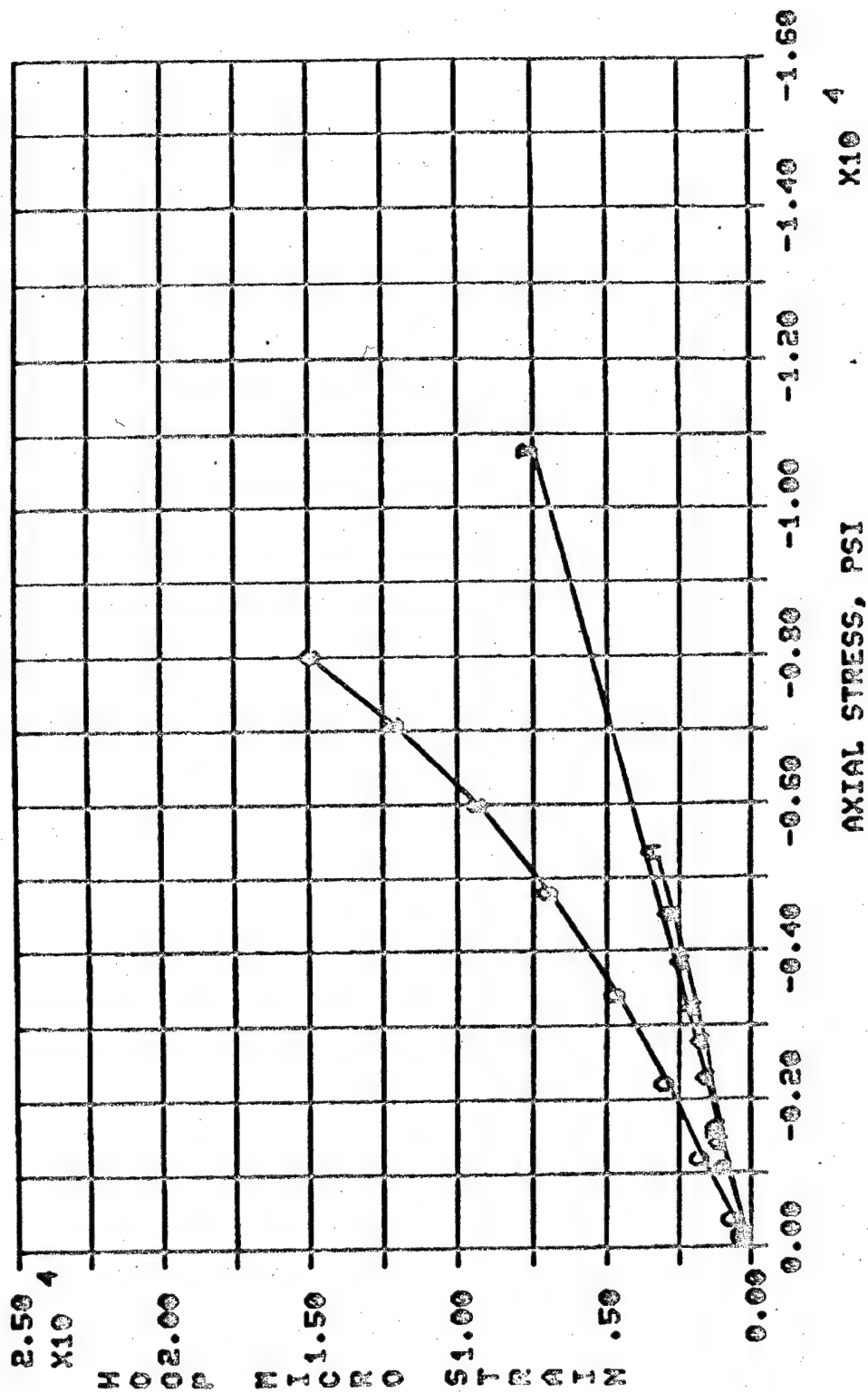


Figure 66 Tests 4-A, B, C. Layout  $\pm 45^\circ$  Axial Only  
Hoop Response, Rosette No. 3

A - Test 4-A  
B - Test 4-B  
C - Test 4-C

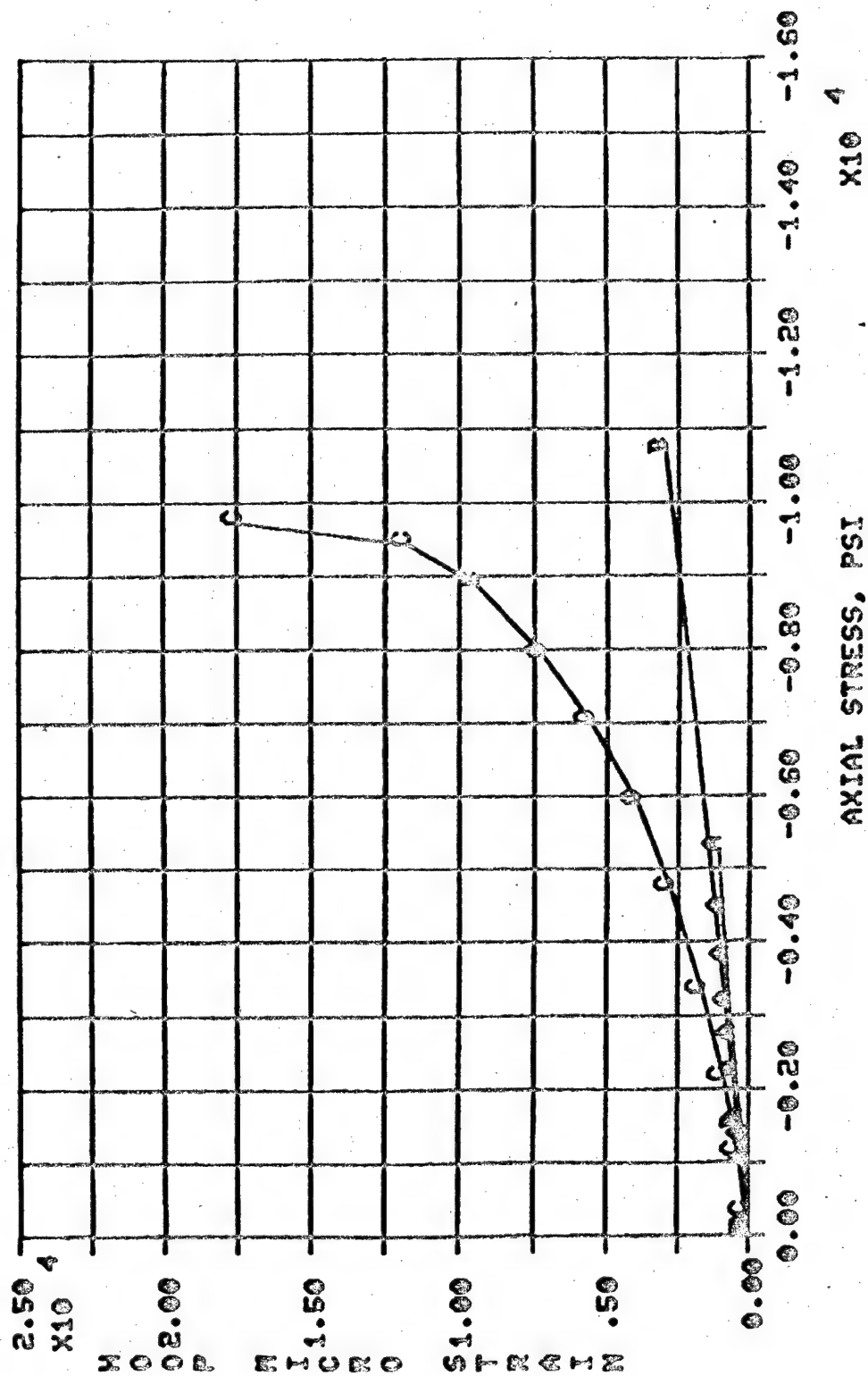


Figure 67 Tests 4-A, B, C. Layout  $\pm 45^\circ$  Axial Only  
Hoop Response, Rosette No. 4

A - Test 4-A  
B - Test 4-B  
C - Test 4-C

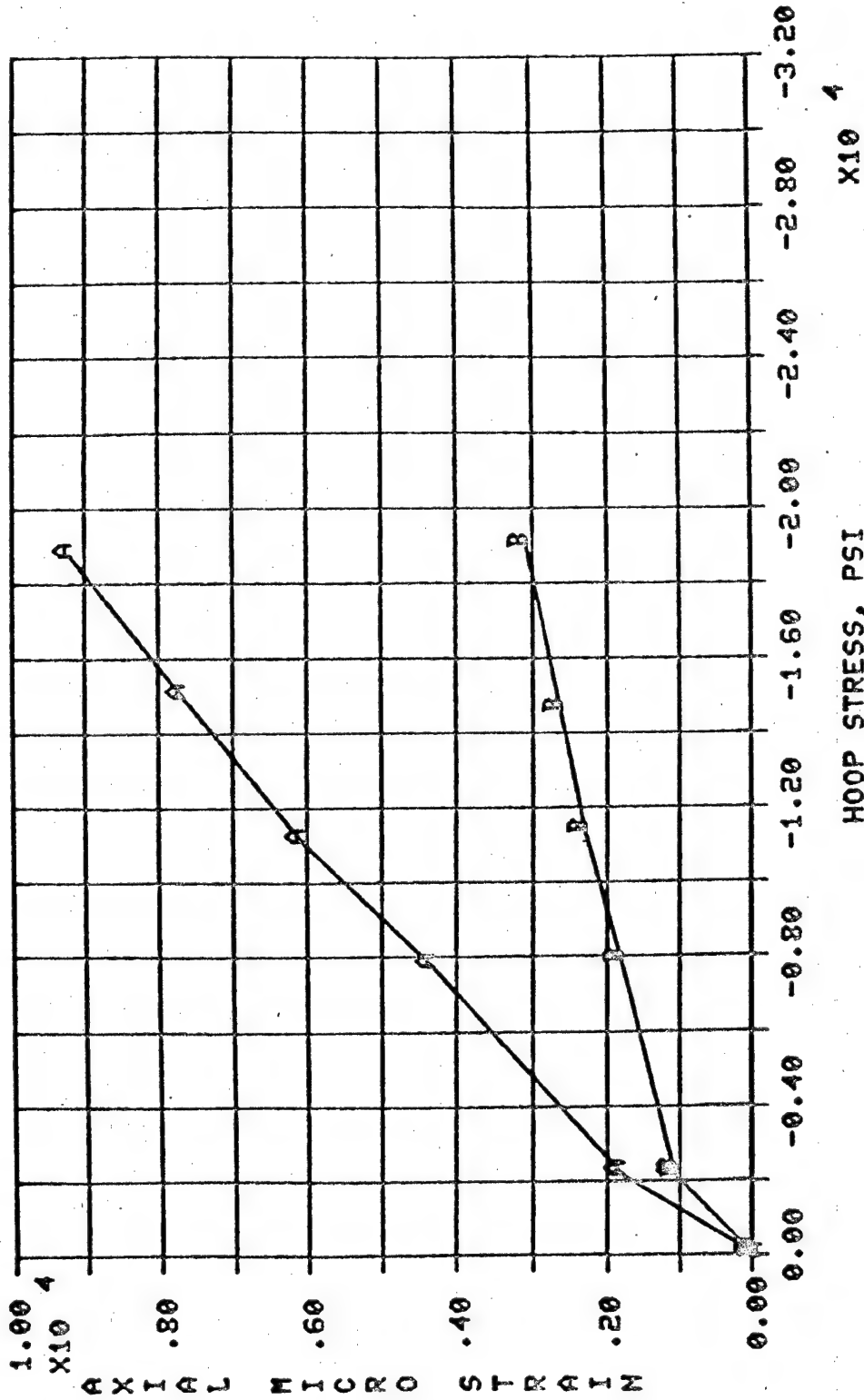


Figure 68 Test 5. Layout  $\pm 45^\circ$  Ext. Pressure  
Axial Response

A - Rosette No. 5  
B - Rosette No. 6

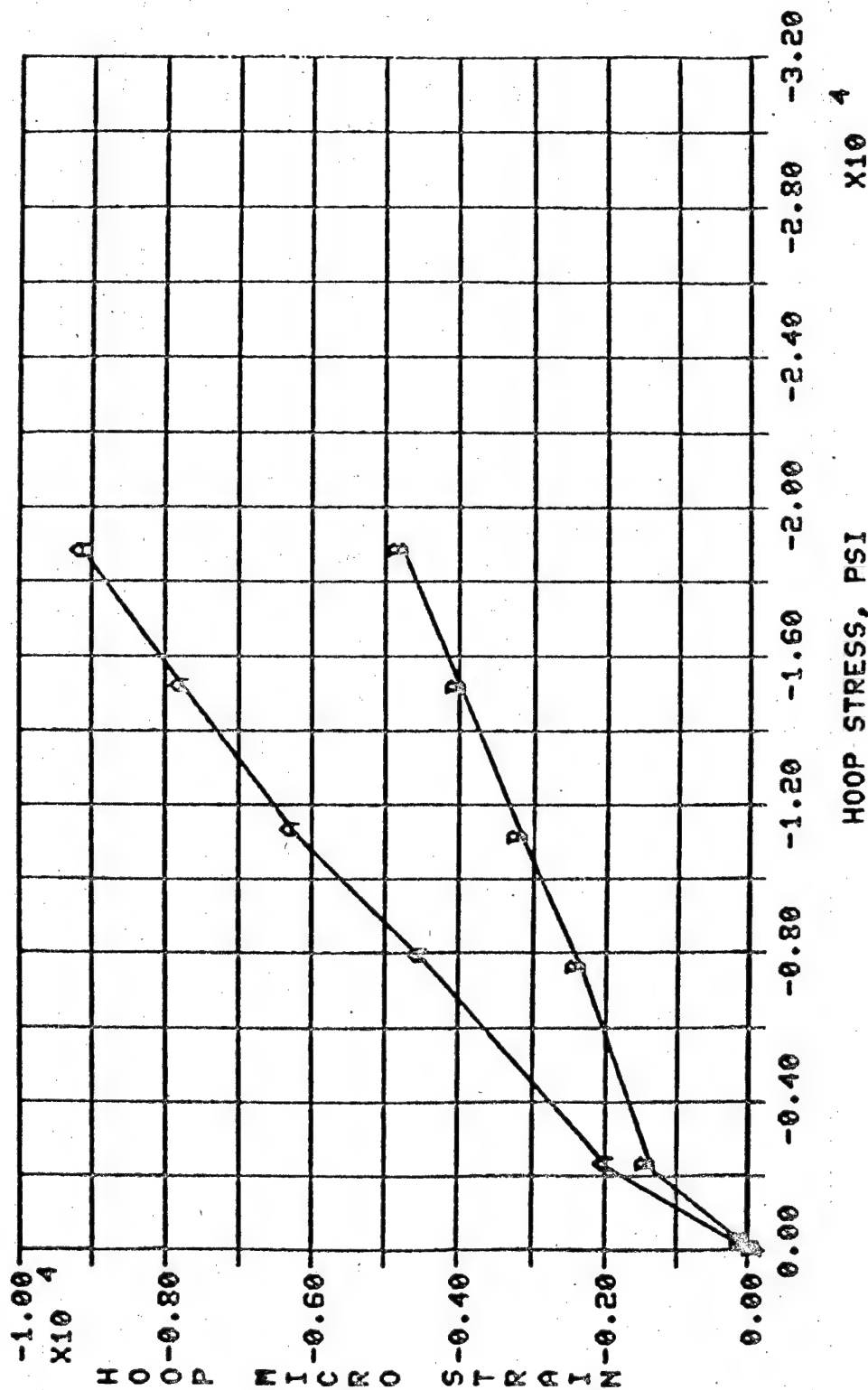


Figure 69 Test 5. Layout  $\pm 45^\circ$  Ext. Pressure  
Hoop Response

A - Rosette No. 5  
B - Rosette No. 6



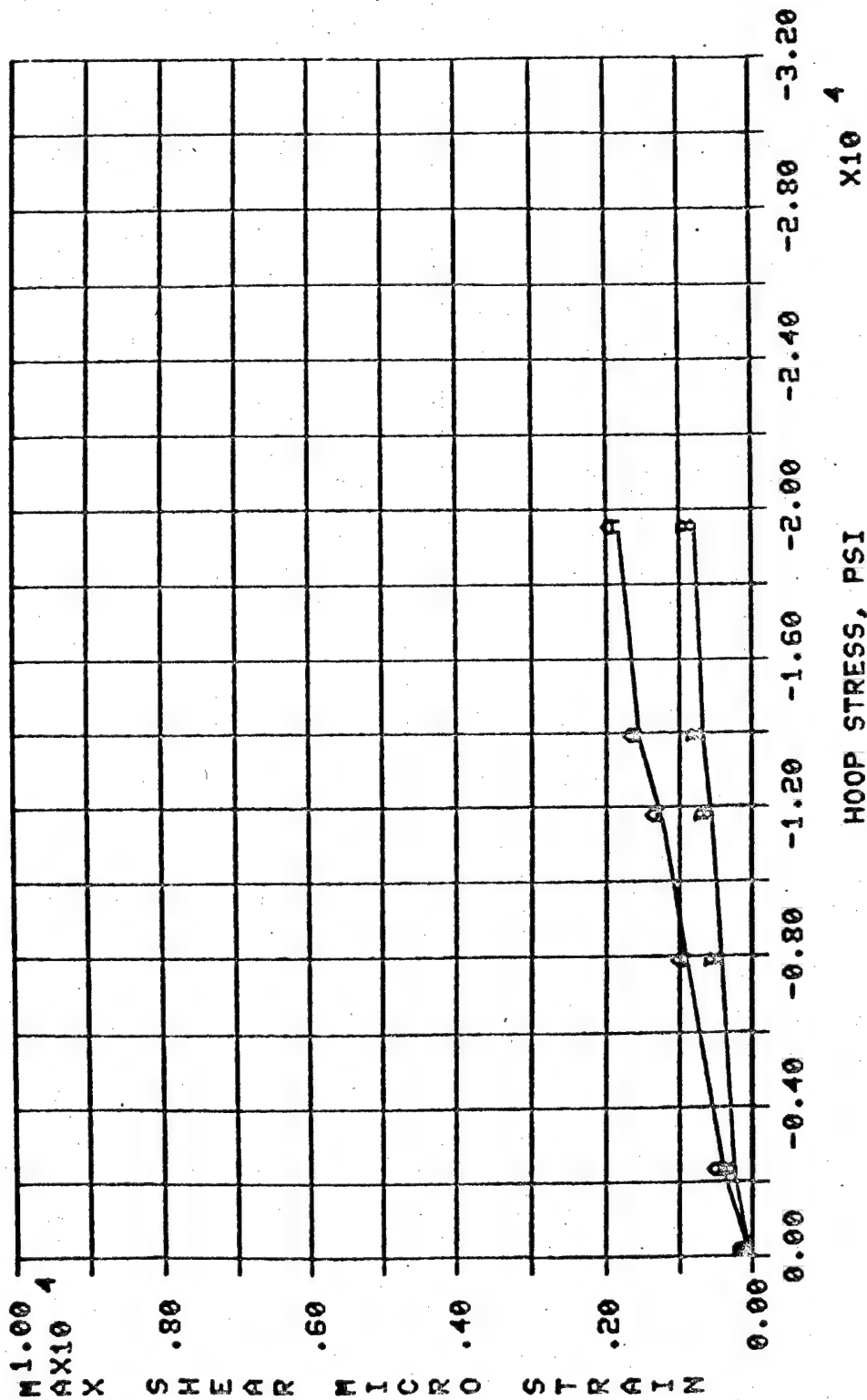


Figure 70 Test 5. Layup  $\pm 45^\circ$  Ext. Pressure  
Max. Shear

A - Rosette No. 5  
B - Rosette No. 6

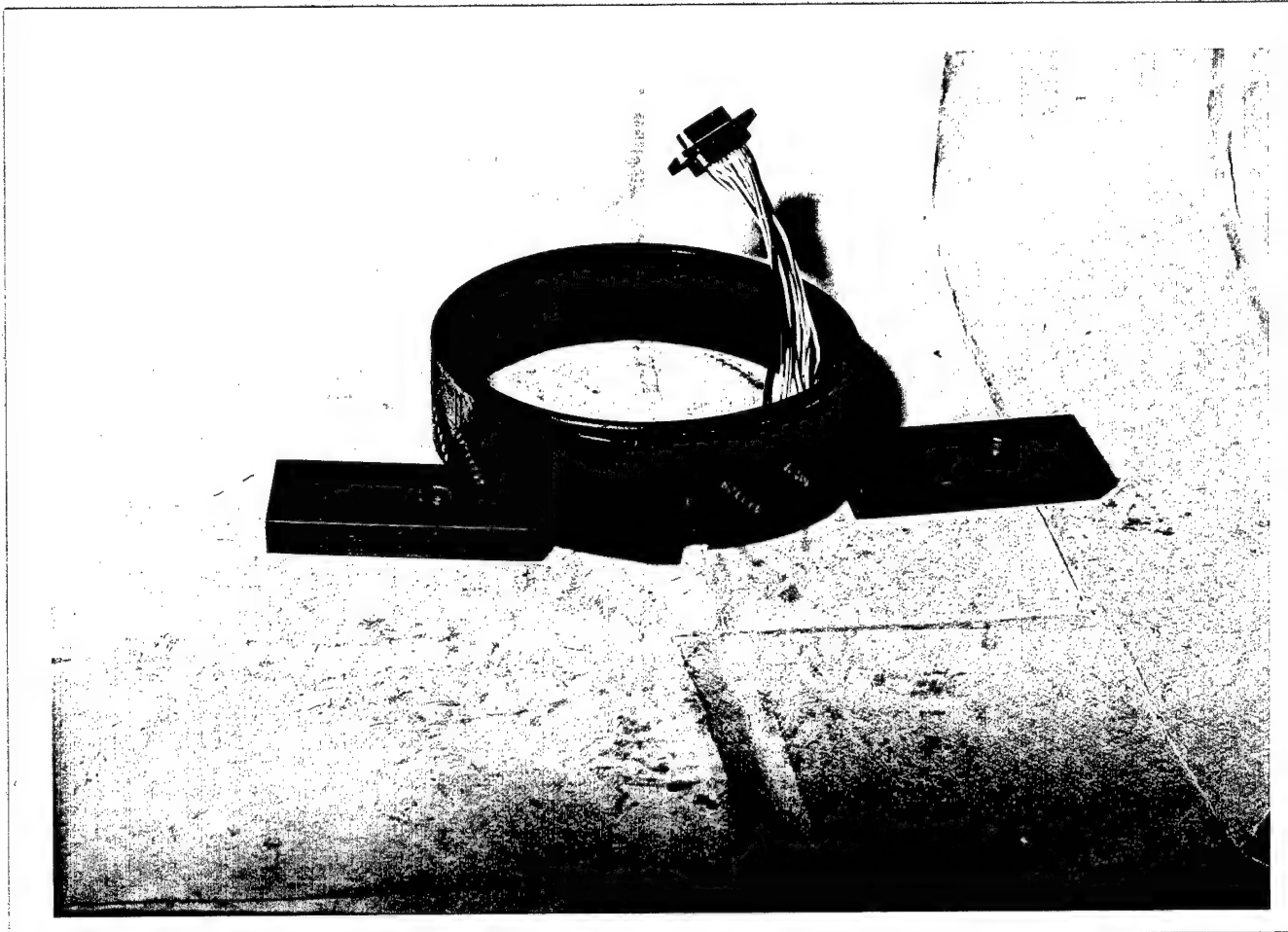


Figure 71 Test Specimen Used in Tests 4-A, 4-B, 4-C and 5 After Fracture from External Pressure. Ply Layup is  $\pm 45^\circ$ .

Both internal pressure and axial load were applied to the specimen for Test 6. The internal pressure was manually servoed to the axial load such that a pure shear condition existed in the specimen. Figure 72 is a plot of the hoop stress versus axial stress. The layup for this specimen was  $0^\circ/\pm 45^\circ/90^\circ$ . Figure 73 is a comparison plot of the axial strain versus axial stress for the rosettes located at the center of the specimen on the outside surface. Strains from Rosette Nos. 1 and 3 are in excellent agreement, and the strain in Rosette No. 2 is very close to these strains. Figure 74 is the axial response of the rosettes located at the edge of the specimen. The strains for these rosettes do not agree with each other. Also, these strains are two to four times higher than the strains recorded at the center of the specimen (see Figure 73). Figures 75, 76 and 77 are comparison plots of hoop strain versus hoop stress with the rosettes located at the center of the specimen on the outside surface, the inside and outside comparison rosettes and the edge rosettes, respectively. The gages at the center on the outside surface are in good agreement, as were the gages at the edge of the specimen. However, the gages recorded strains approximately twice as large as the center gages. The inside-outside comparison gages were in very poor agreement. The maximum shear strain plots for this test were uninterpretable and are not reproduced here. The final failure in Test 6, shown in Figure 78, was from a fracture running approximately half-way across the specimen at a  $45^\circ$  angle. The fracture then changed directions and propagated the remainder of the way across the specimen in an axial direction. The final fracture was accompanied by eight  $45^\circ$  partial fractures distributed around the specimen.

Test 7 was to be conducted such that hoop stress equaled axial stress. The loads were applied using external pressure and axial load. The specimen layup was  $0^\circ/\pm 45^\circ/90^\circ$ . Figure 79

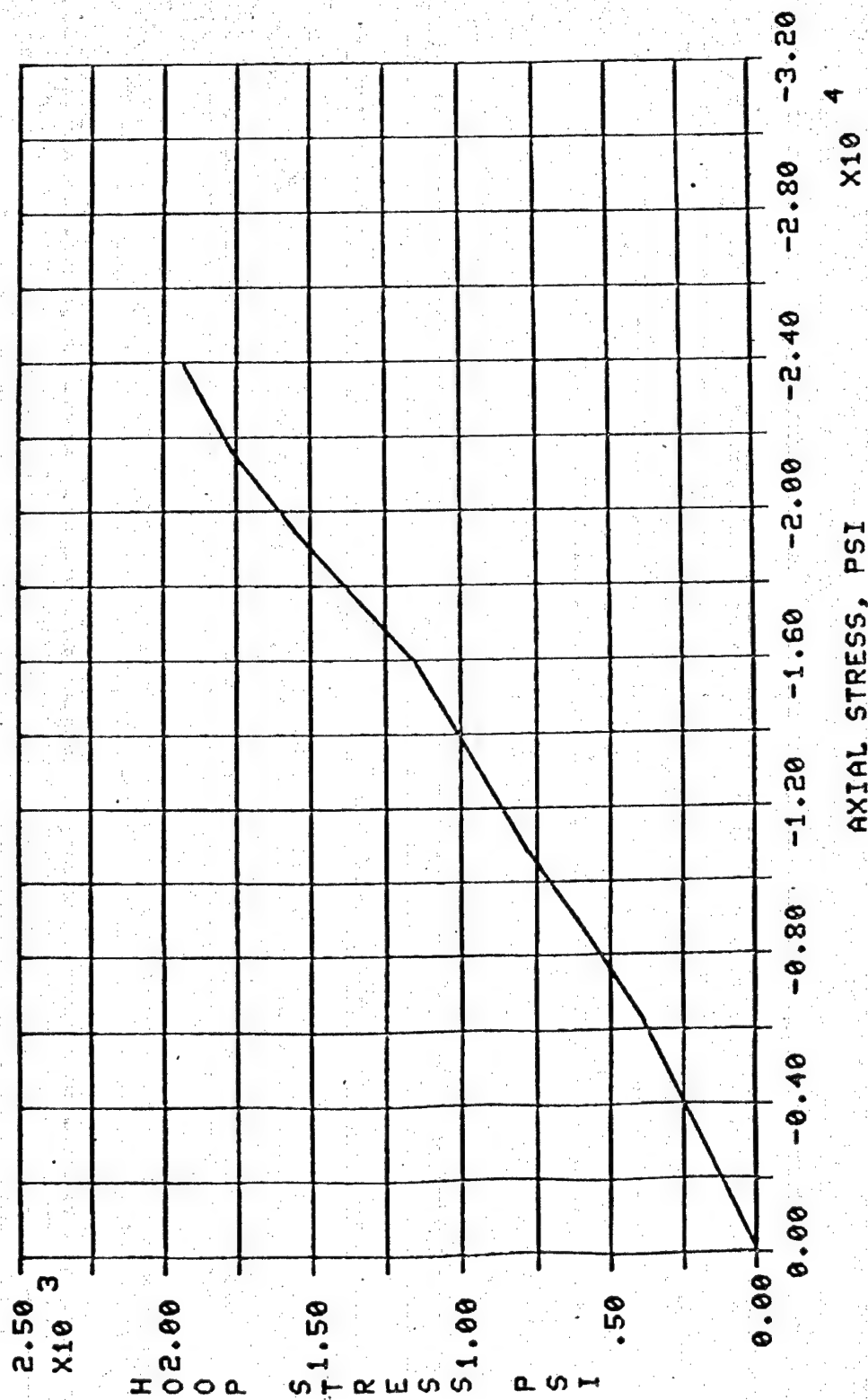


Figure 72 Hoop Stress Versus Axial Stress for  
Test 6

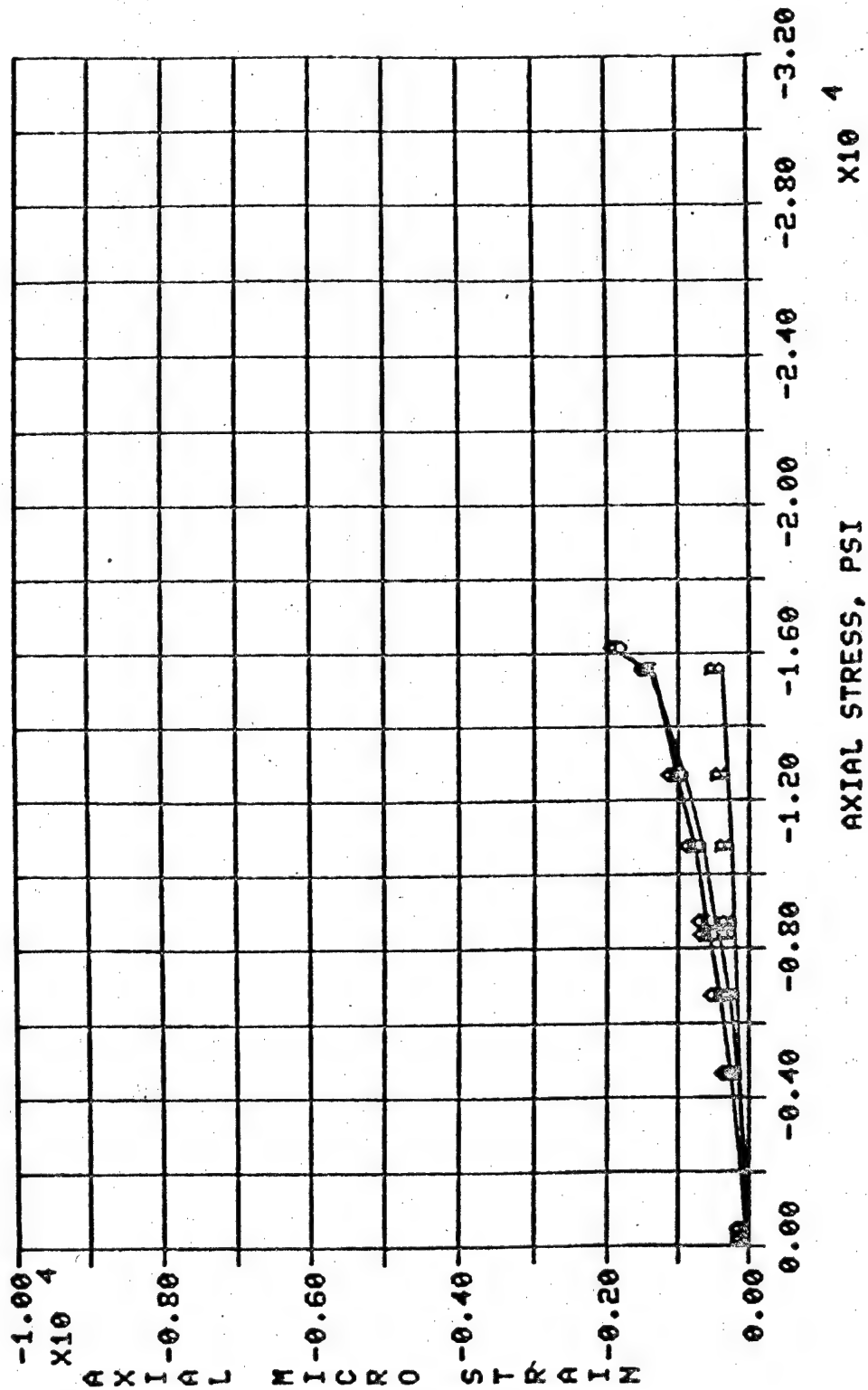


Figure 73 Test 6. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Pure Shear Load  
Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3

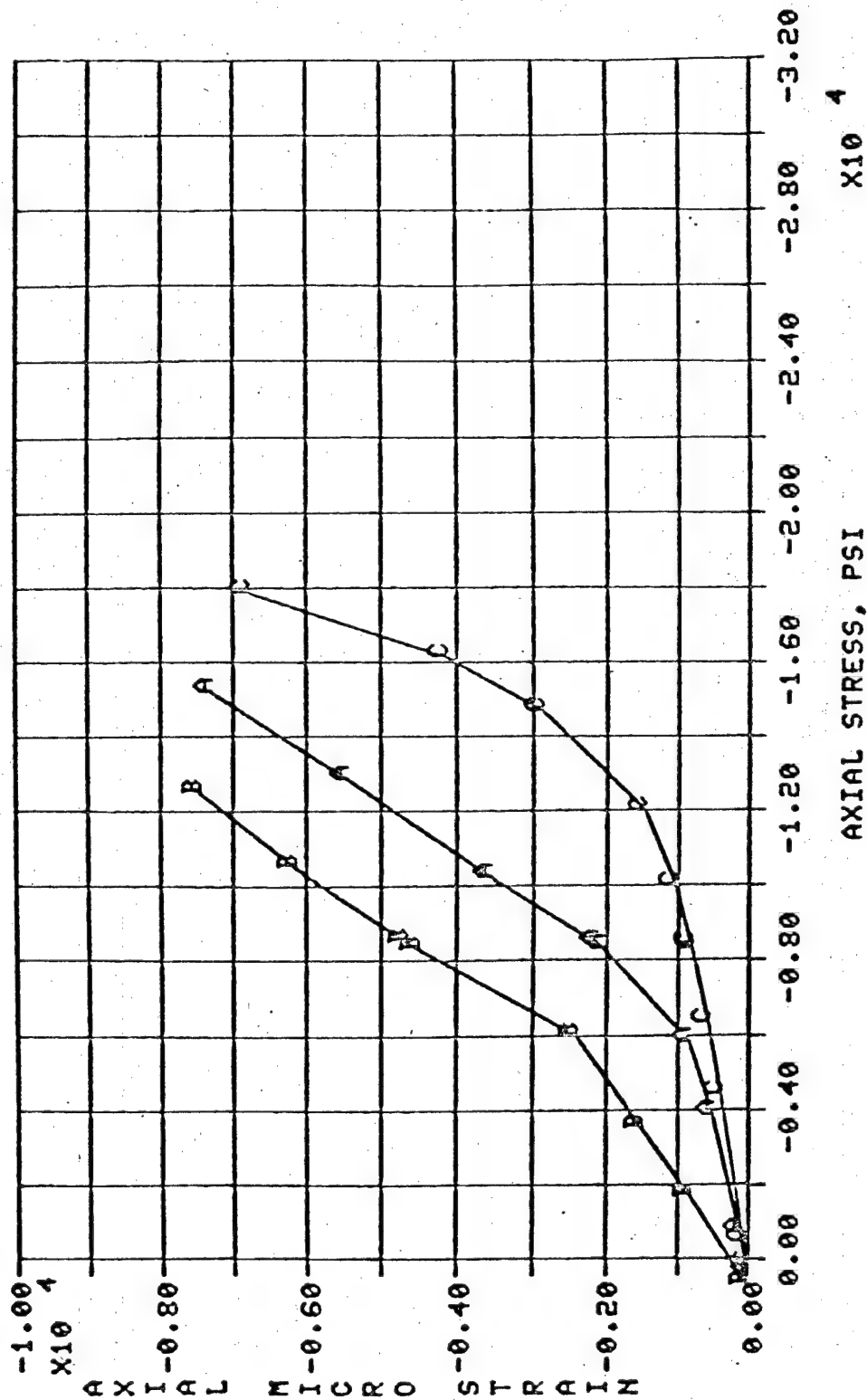


Figure 74 Test 6. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Pure Shear Load  
Axial Response, Edge Rosettes

A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8

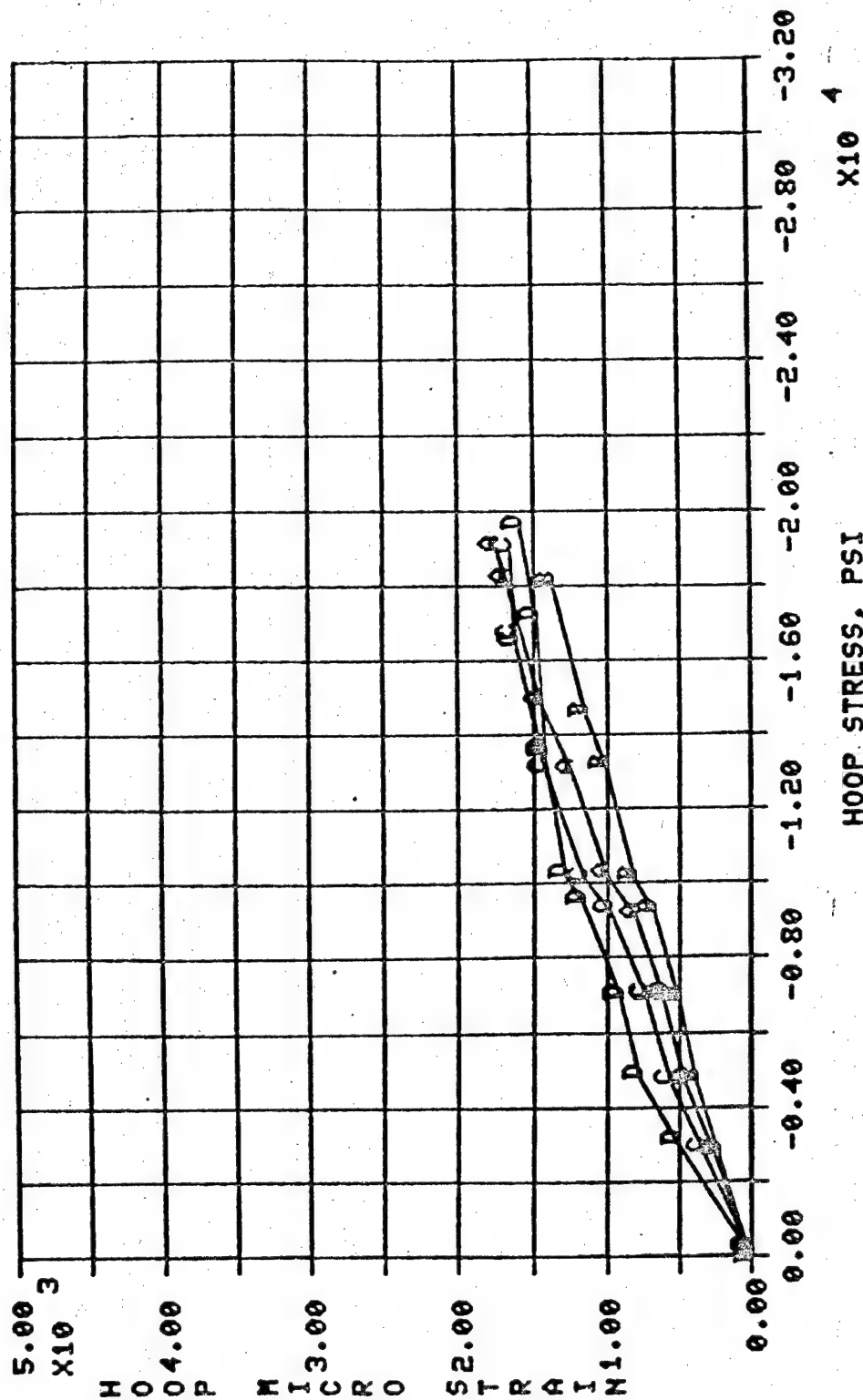


Figure 75 Test 6. Layup 0°/±45°/90° Pure Shear Load  
Hoop Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

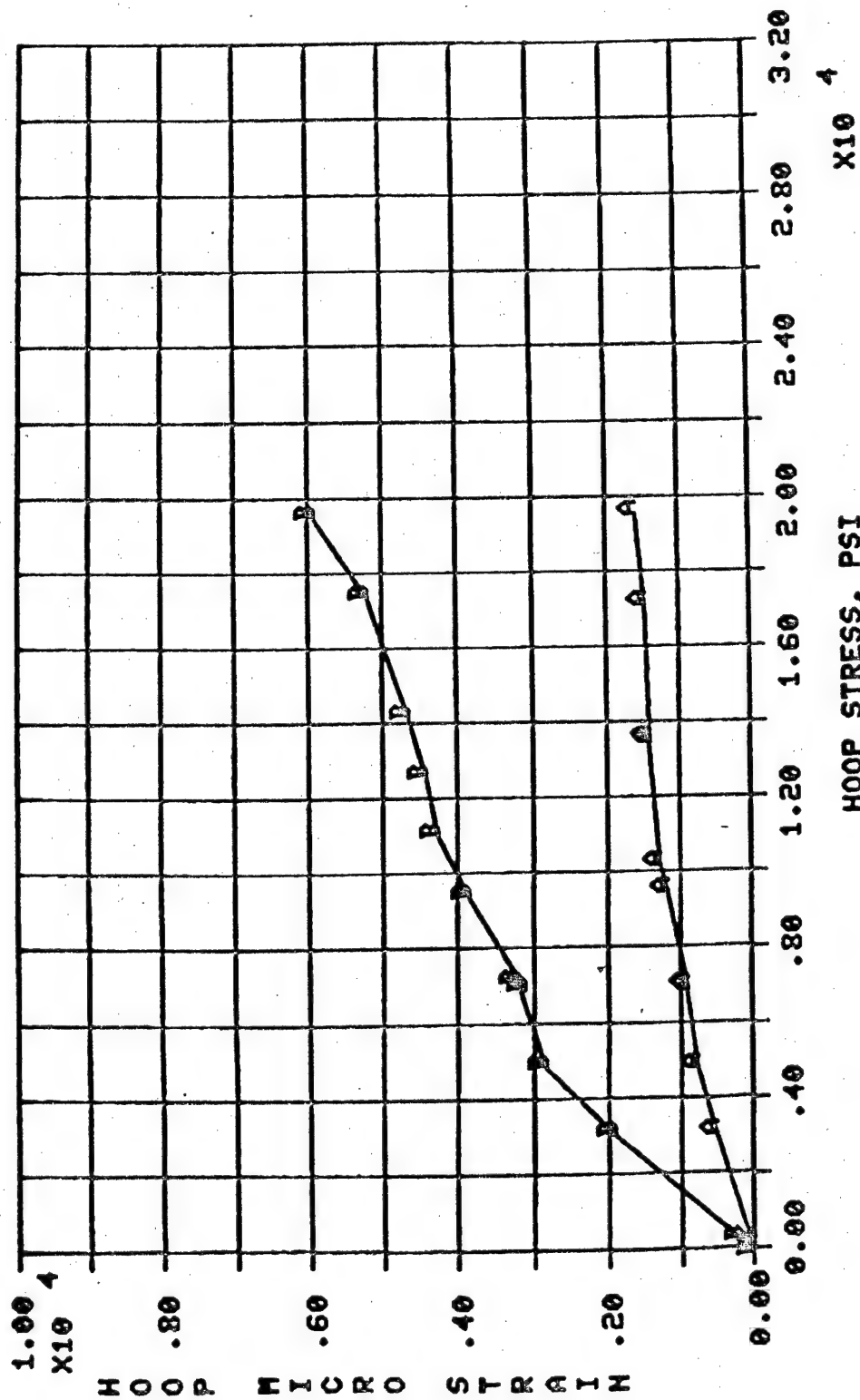


Figure 76 Test 6. Layup  $0^\circ/\pm 45^\circ/90^\circ$  Pure Shear Load  
Hoop Response, Inside/Outside Rosettes  
Least Squares Fit

A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)



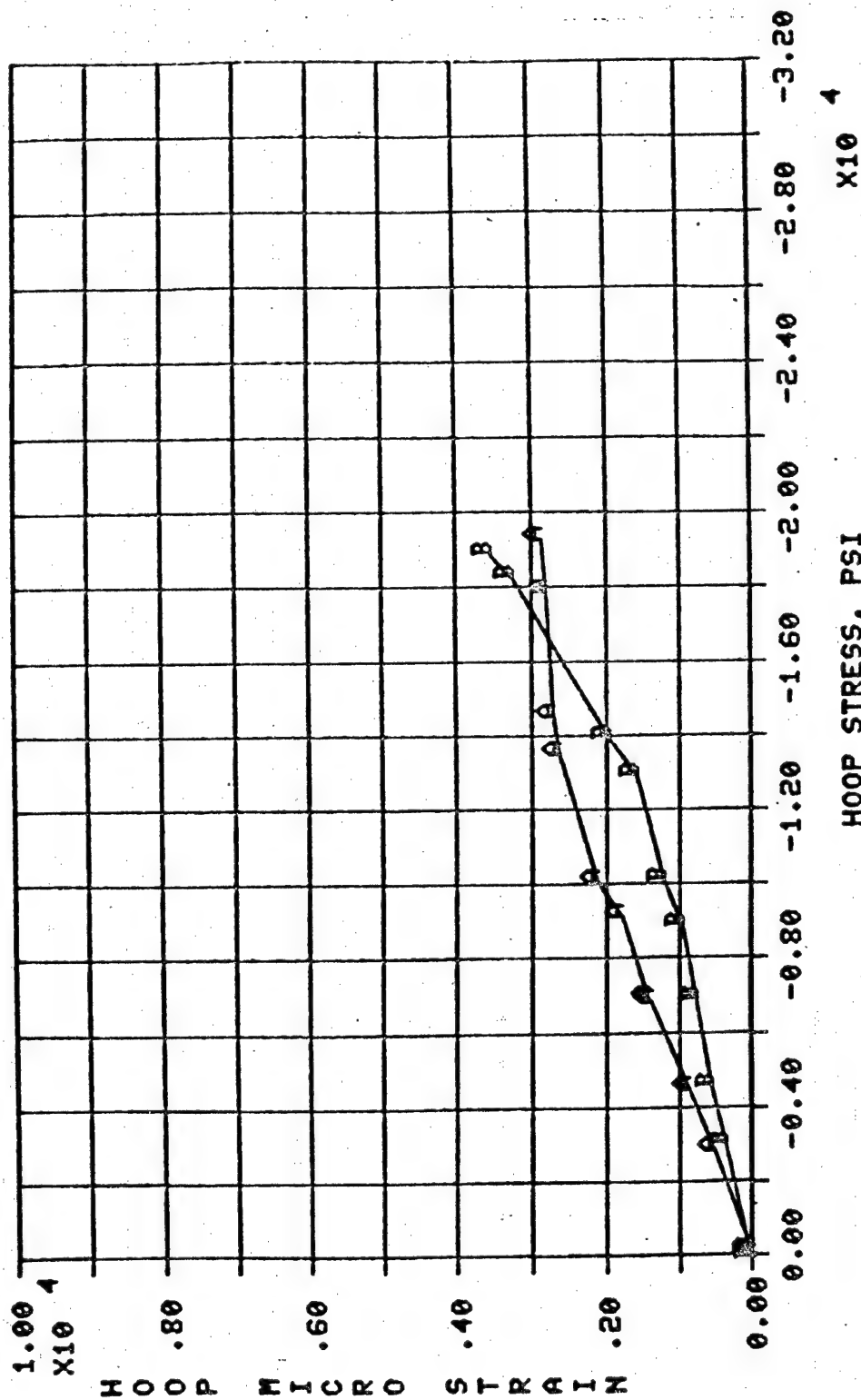


Figure 77 Test 6. Layup  $0^\circ/\pm 45^\circ/90^\circ$  Shear Load  
Hoop Response, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8

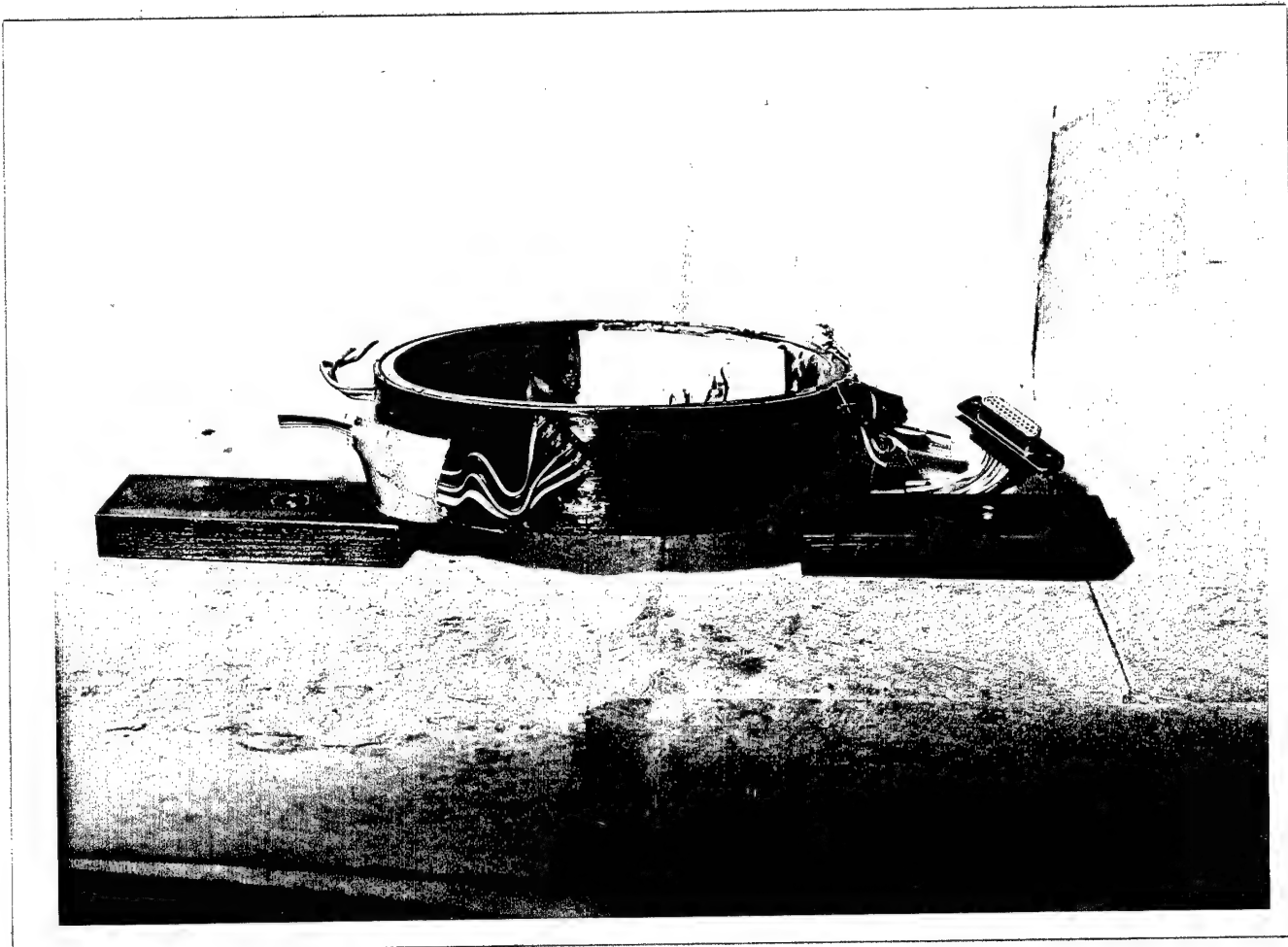


Figure 78 Test Specimen No. 6 After Failure from Internal Pressure and Axial Load. Stress Conditions were Equivalent to Pure Shear. Ply Layup is  $0^\circ/\pm 45^\circ/90^\circ$ .

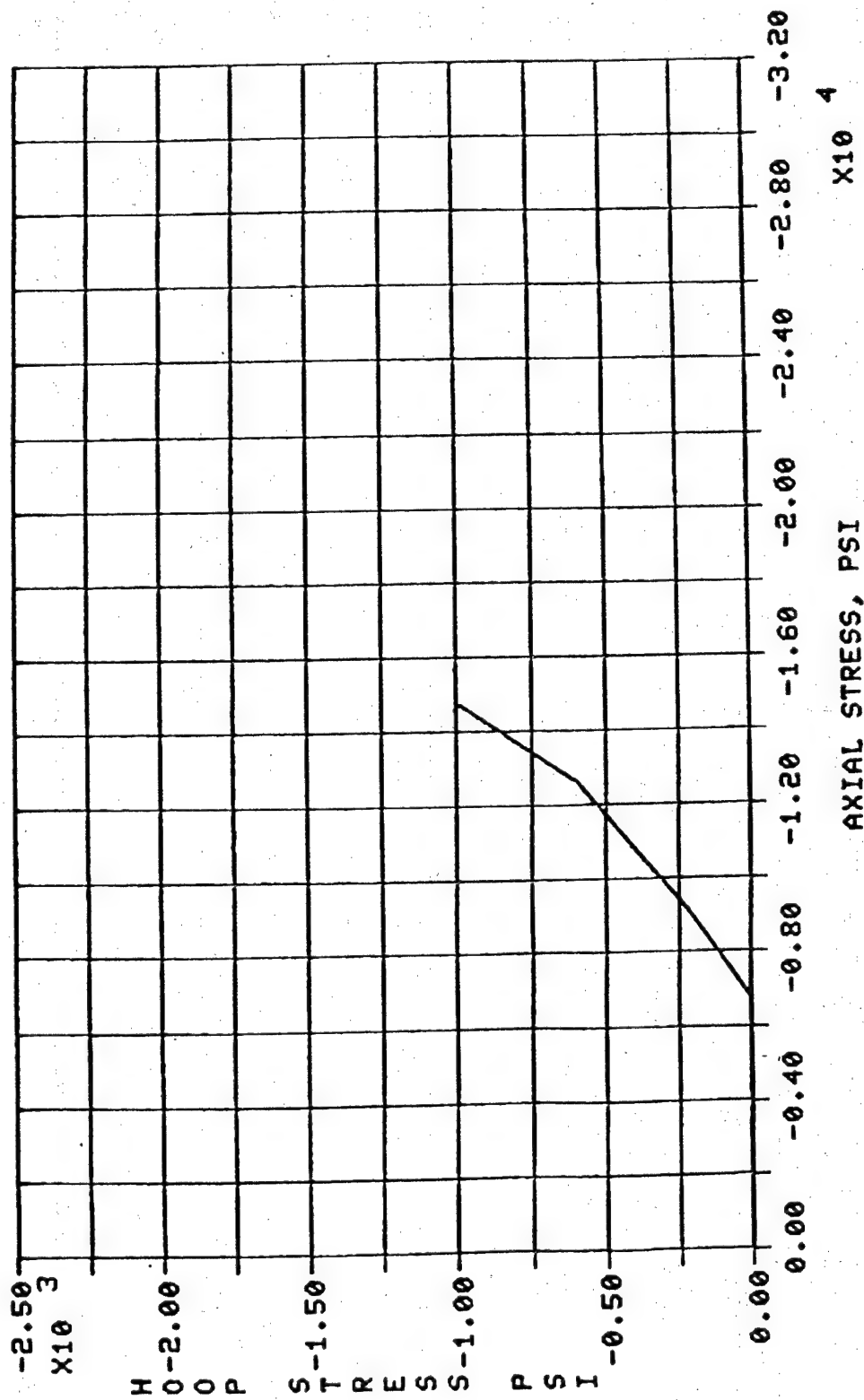


Figure 79 Hoop Stress Versus Axial Stress for Test 7

is a plot of the hoop stress versus axial stress. An axial stress of 7000 psi compression was applied to the specimen before any external pressure was applied. The external pressure was manually servoed to the axial load. In the future, this type of test (test with a loading manually servoed) should be conducted much slower to allow adequate reaction time. Strain gage output during Test 7 was erratic. As the specimen could not be observed through the external pressure collet, it is not known with certainty why the erratic strains arose. Figures 80 through 86 are the comparison strain plots for this test. Very poor agreement was obtained between the gages located along the outside center of the specimen; however, the gages between the inside and outside surfaces produced axial results in agreement. The remaining results from this test indicate that hourglassing or buckling could have been taking place. Figure 87 is a photograph of the specimen used in Test 7 after failure occurred.

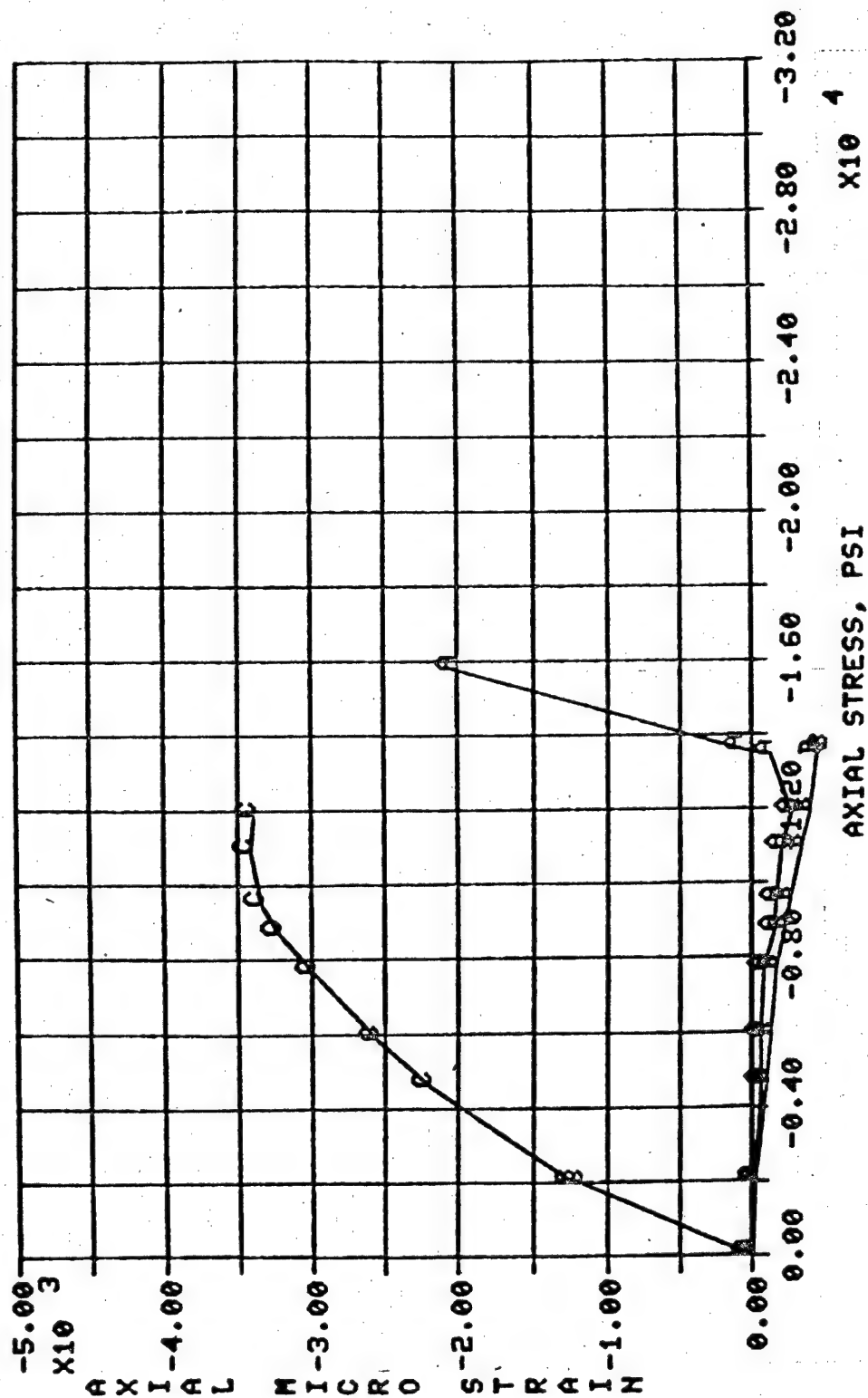


Figure 80 Test 7. Layout 0°/±45°/90° Axial & Ext. Pr.  
Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3

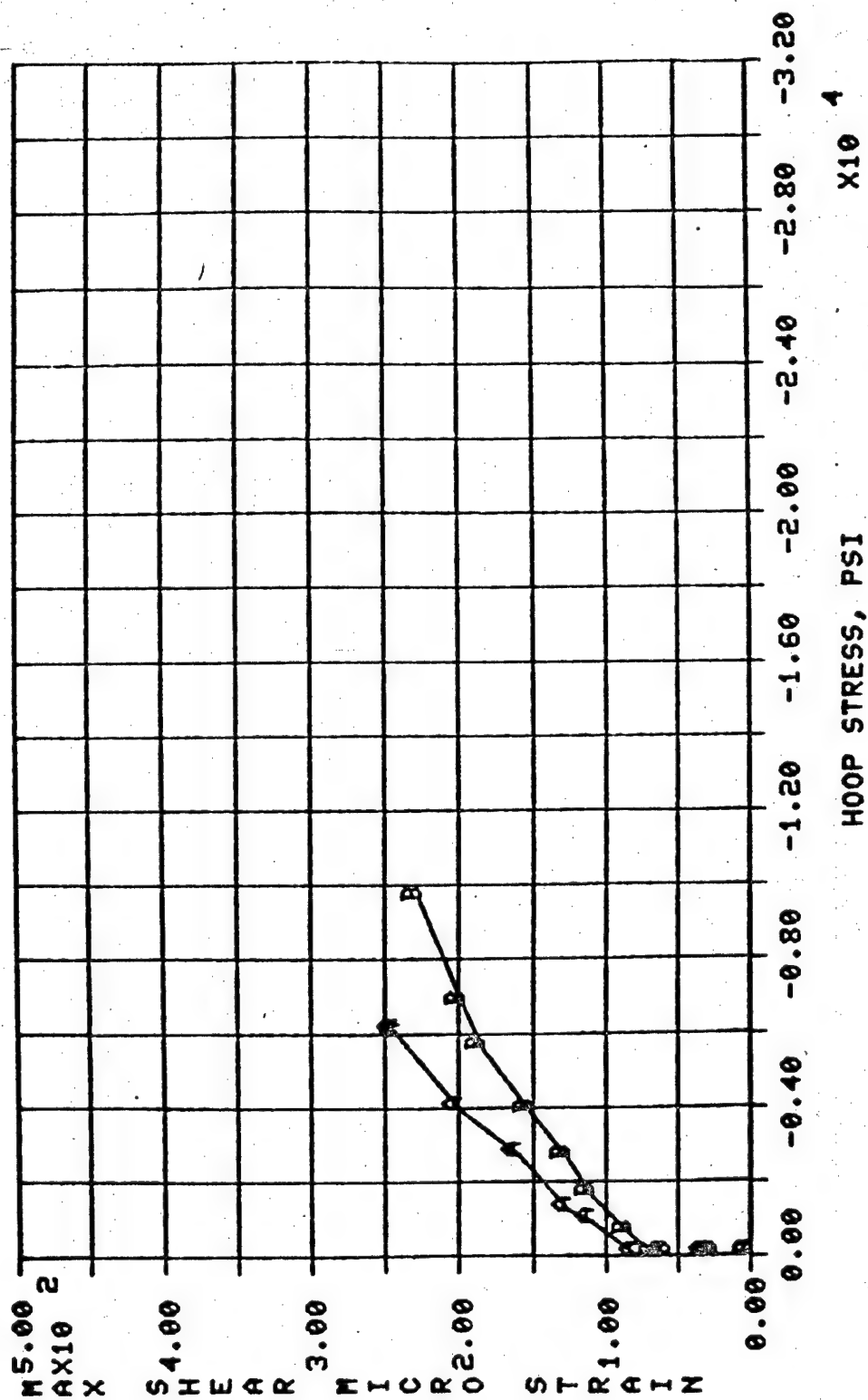


Figure 81 Test 7. Layout 0°/±45°/90° Axial & Ext. Pr.  
Max. Shear, Outside Rosettes  
A - Rosette No. 1  
B - Rosette No. 2

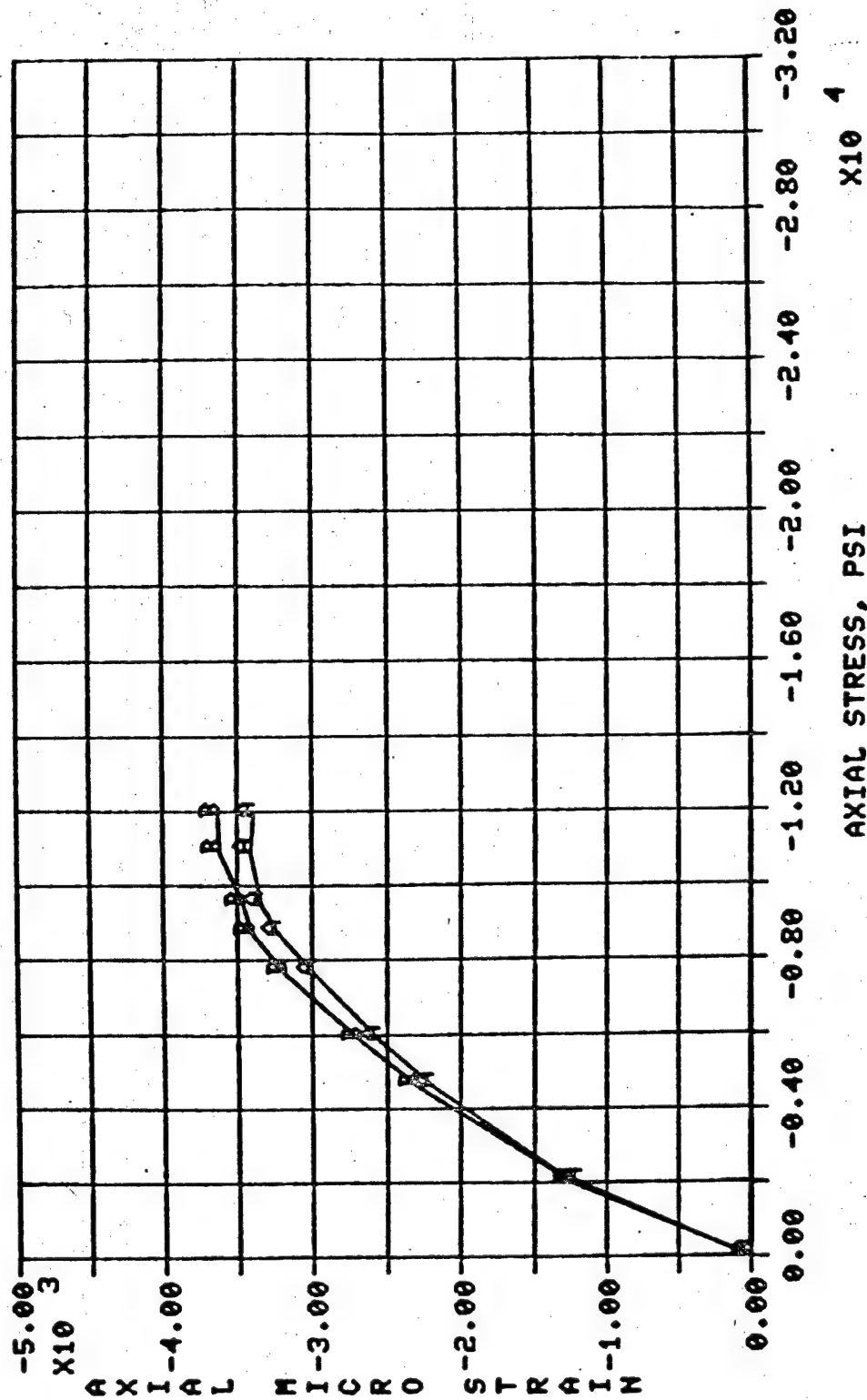


Figure 82 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)

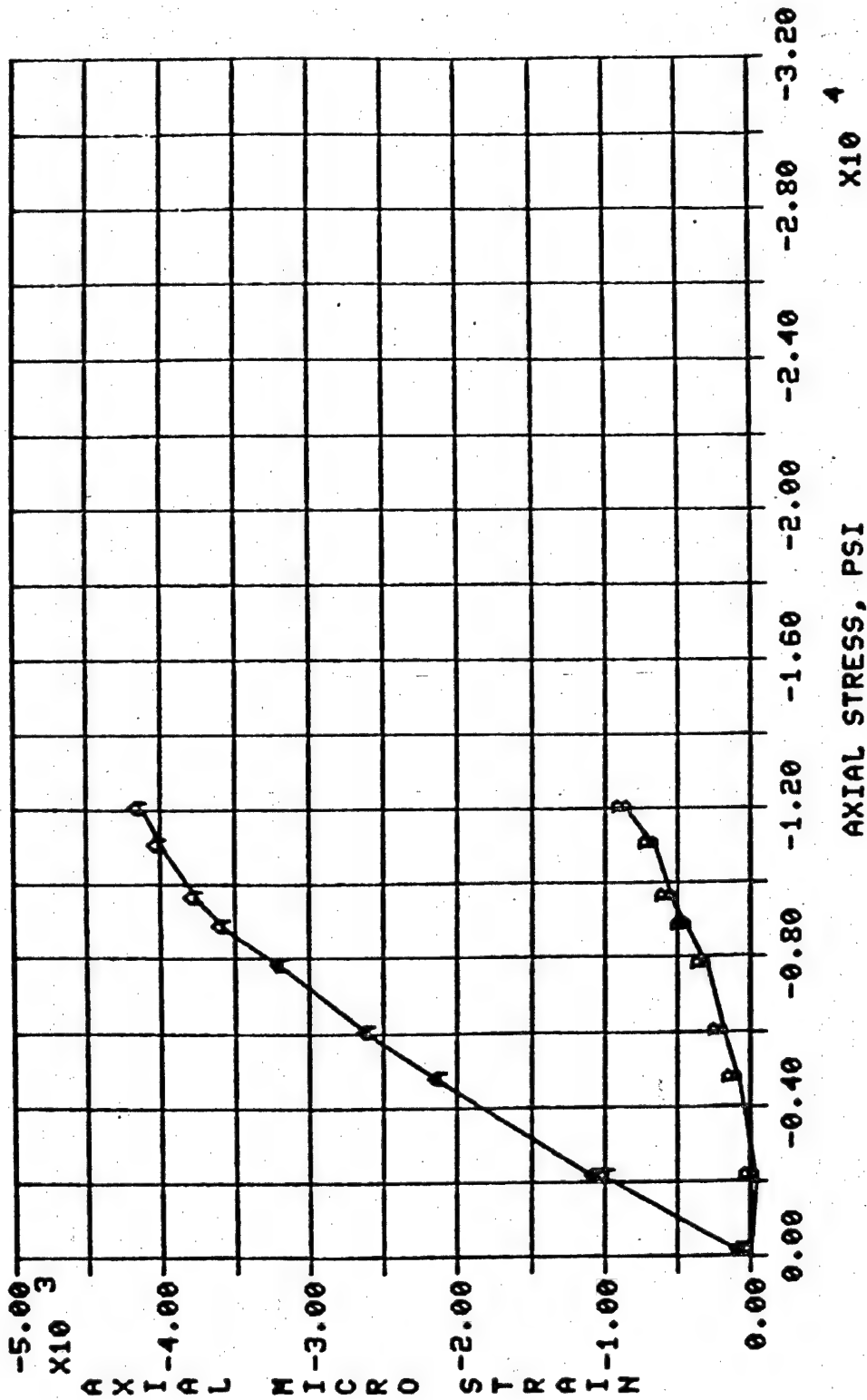


Figure 83 Test 7. Layout 0°/±45°/90° Axial & Ext. Pr.  
Axial Response, Edge Rosettes

A - Rosette No. 7  
B - Rosette No. 8



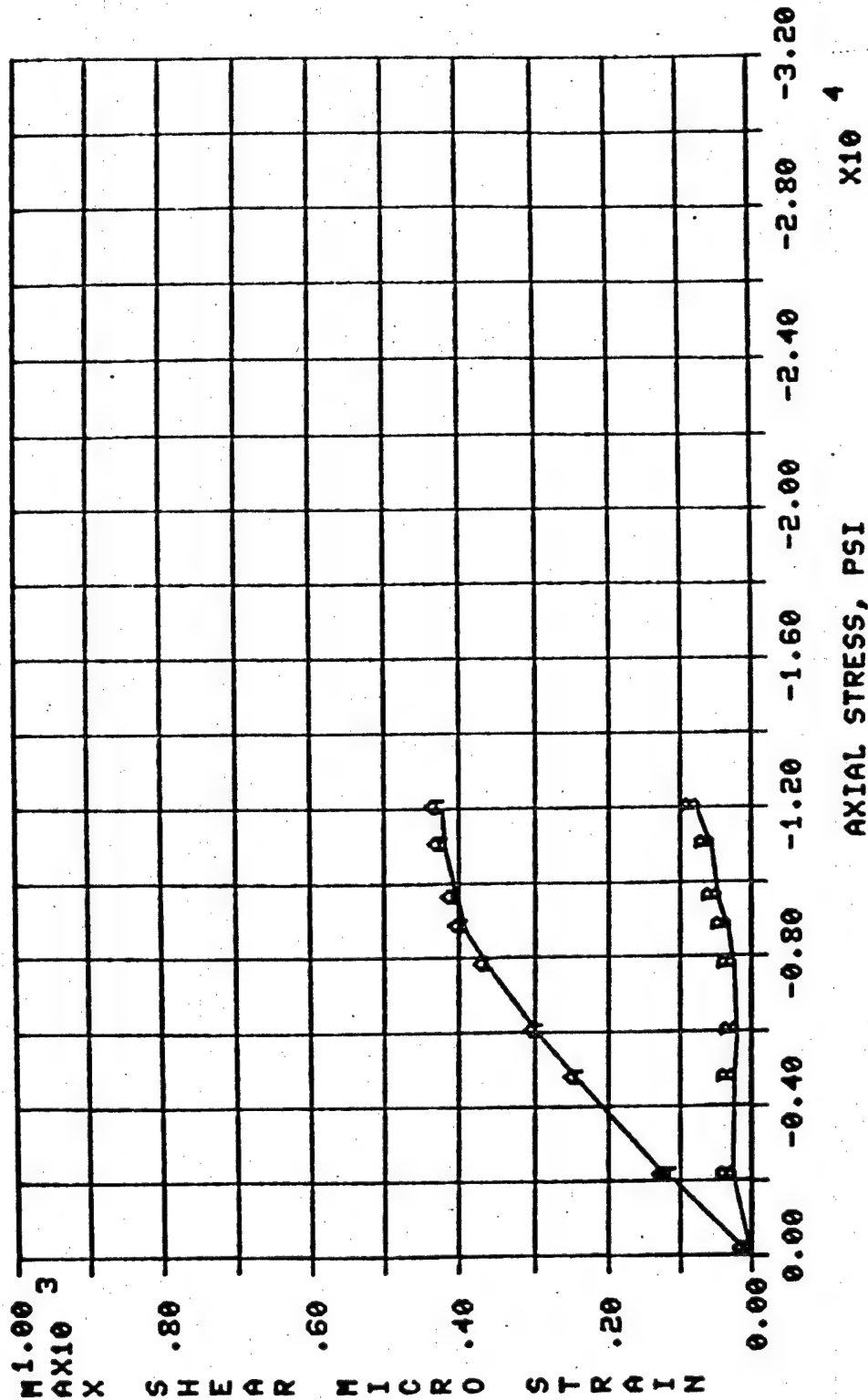


Figure 84 Test 7. Layout  $0^\circ/\pm 45^\circ/90^\circ$  Axial & Ext. Pr.  
Max. Shear, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8

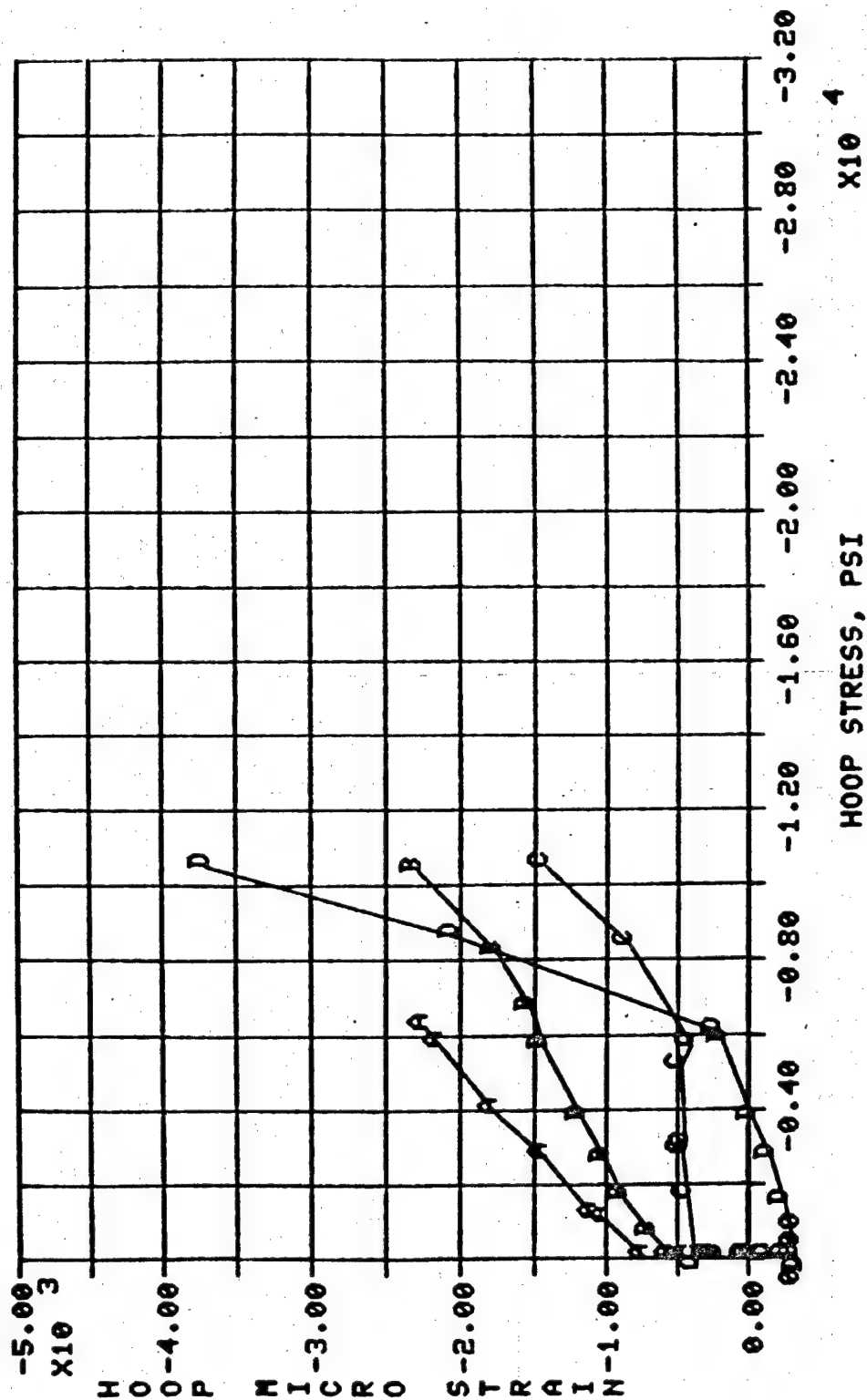


Figure 85 Test 7. Layout 0°/±45°/90° Axial & Ext. Pr.  
Hoop Response, Outside Rosettes

- A - Rosette No. 1
- B - Rosette No. 2
- C - Rosette No. 3
- D - Rosette No. 4

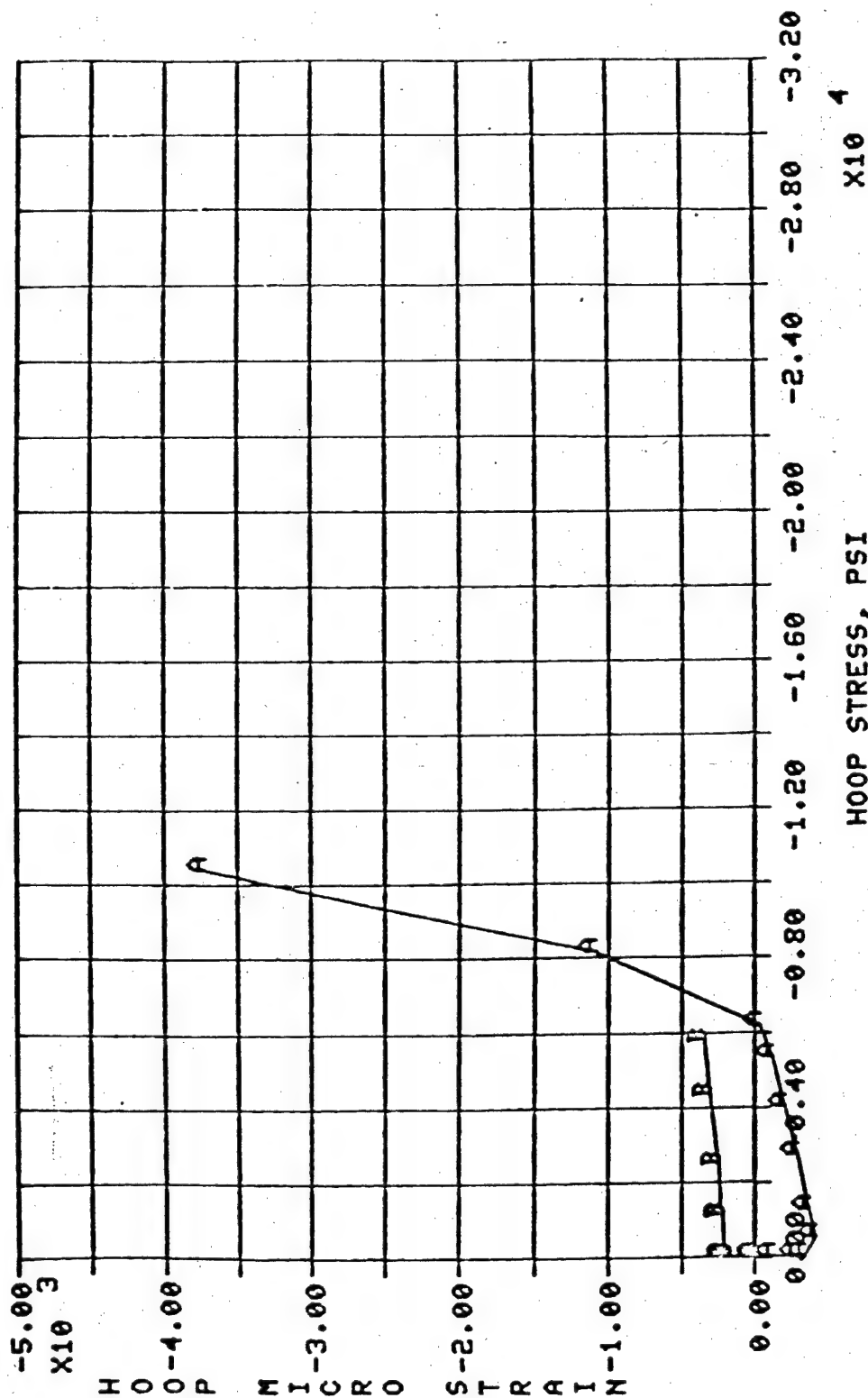


Figure 86 Test 7. Layout 0°/±45°/90° Axial & Ext. Pr.  
Hoop Response, Edge Rosettes  
A - Rosette No. 7  
B - Rosette No. 8

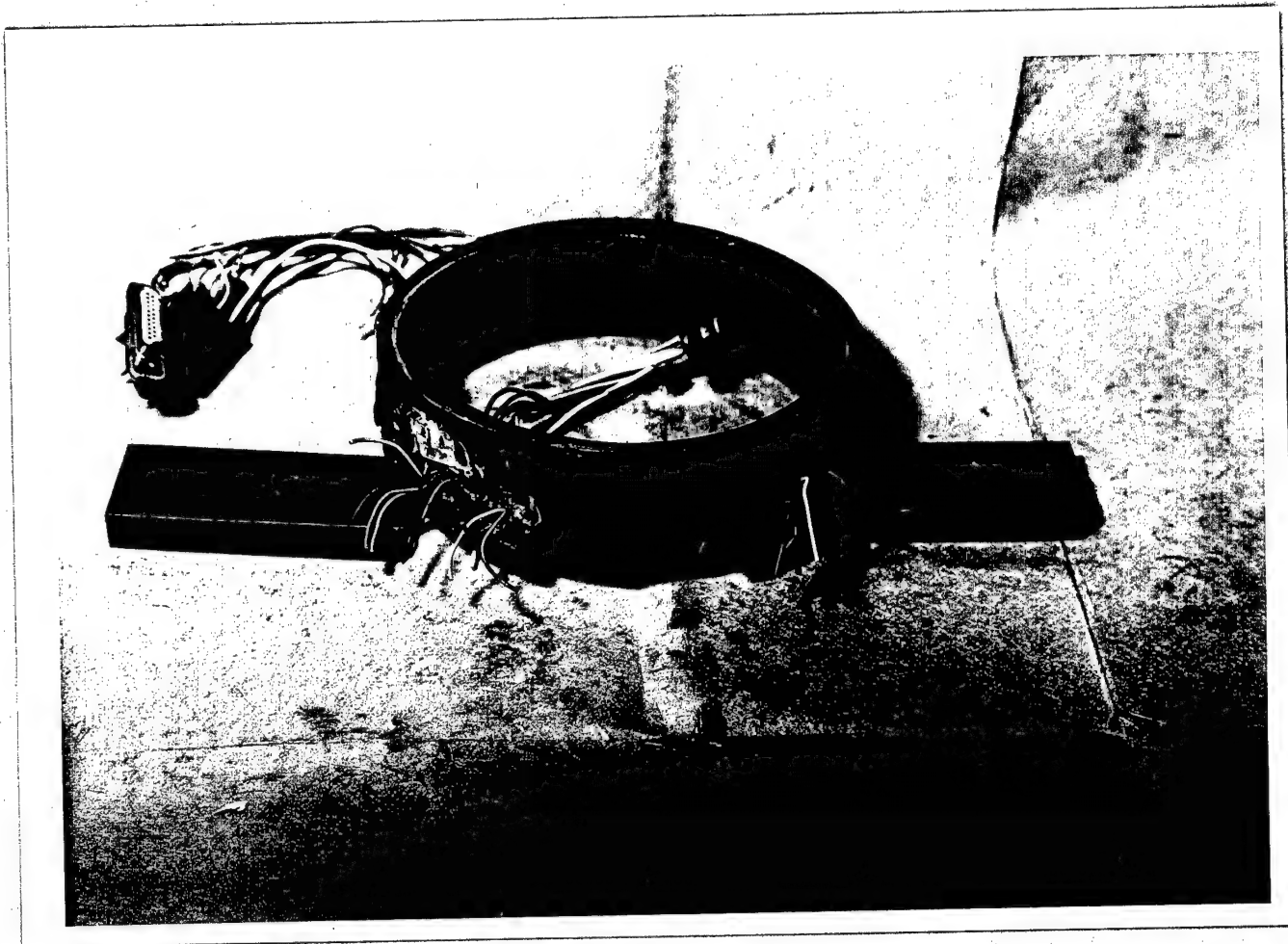


Figure 87 Test Specimen No. 7 After Failure  
from Axial Load and External Pressure.  
Stress Conditions Were Such That Axial  
Stress Equaled Hoop Stress. Ply Layup  
is  $0^\circ/\pm 45^\circ/90^\circ$ .

## V. CONCLUSIONS

Based on the testing, the test technique has been shown to be promising as a simple test system for determining the biaxial properties of materials. In the early elastic regime, elastic properties may be determined for compression-compression, as well as for tension-compression. The fixture has demonstrated its ability to apply axial compression, internal or external pressure, or a combination of loadings. It appears that the solid lubricant system works well in retaining the pressure while allowing the ends to be relatively free of constraint.

Although the fixture was originally designed for biaxial tests, it has been shown to be capable of rupturing high Poisson's ratio tubes under internal pressure. This is possible as the platens may be advanced as the specimen length decreases so that no gap appears and oil pressure is maintained. Prior to the development of this fixture, free end constraint internal pressure tests on high Poisson's ratio tubes could not be performed.

The tests to date have only demonstrated that the testing technique is very promising. Additional tests need to be performed to improve the fixture and demonstrate repeatability of the results on identical specimens. Different length specimens, such as .5 inches and 2.0 inches, should be tested.

APPENDIX A

LISTING OF  
COMPUTER PROGRAM  
"STRAINS"

### COMPUTER PROGRAM "STRAIN"

As part of the effort reported here, a computer program was developed for processing strain gage data. The program is specifically tailored to the Sun System used by Anamet for monitoring and digitizing strain gage data readings. It is presently running on Anamet's PDP 11/34 under RSX-11M, in an interactive mode. All the plots reproduced in this report were generated by the computer on a Tektronix 4014 display screen.

STRAIN operates in two phases. First, a raw data file, which has been transferred directly from the Sun System to disk, is read and checked for format errors and for overload or open circuit conditions. The information is sorted by channels and stored in a binary disk file. The user is asked to identify each channel as either a load channel or a strain channel. For strain channels, the rosette number and the leg of the rosette are requested. Raw data files may consist of one or more test runs, each with different assignments of data channels. Once the binary file has been established, the second phase may be executed repeatedly to obtain plots and/or print-outs of reduced data.

In the second phase, the user is asked to supply the constants required to convert load data to stresses, thus making the program independent of the geometry of the specimen. Two load channels are provided for: an axial force channel and a pressure channel. Eight rosettes are allowed. For each plot to be generated, the user may choose to plot either stresses or strains on either axis. These may be direct stresses and strains, or principal stresses and strains, calculated by the program. As many as eight curves may be drawn on a single plot, with the user choosing a different rosette for each curve, and if the data file contains multiple runs, the curves may be selected from different runs. The user is also given the option to print the data that is plotted. The values plotted on the vertical axis are interpolated to agree with the times corresponding to the values on the horizontal axis.

PORTRANT IV V02.04 PAGE 001  
CORE=31K, UIC=(212,1) PM 04-JAN-80 09146152 ,STRAIN/EX=STRAIN

```

0001      PROGRAM STRAIN
C
C      PROGRAM TO DIGEST AND PLOT DATA FROM SUN SYSTEM
COMMON/MISC/NRUN,TLD(10,2),TDIK(10,3),JOBIII(60)
BYTE TLD,TDIR,JOBIII
COMMON/CONTROL/REPEAT,JPLI(2)
LOGICAL REPEAT
COMMON/BINARY/STUFF(19932)
BYTE STUFF,FNAME(30)
EQUIVALENCE (STUFF,FNAME)
COMMON/SLD/SL(3,2,2)
LOGICAL WANT,NEW
DATA LSTUFF/19932/
CALL ERASE
CALL CLEAR(SL,24)
CALL DISPLAY
1('ANALYST SUN SYSTEM STRAIN GAGE DATA REDUCTION & PLOTTING PROGRAM')
REPEAT=.FALSE.
CALL DISPLAY('NOTE: TO SELECT DEFAULT INPUT VALUES, STRIKE RETURN')
CALL PAUSE
NEW=.NOT.WANT
1('HAS A BINARY FILE ALREADY BEEN CREATED FOR THIS JOB')
IF (NEW)
1CALL ASSIGN(1,FNAME,ISREAD('RAW DATA FILE NAME',FNAME,3,30))
CALL ASSIGN(2,FNAME,ISREAD('BINARY DATA FILE NAME',FNAME,3,30))
CALL DISPLAY
1('IF NO PRINT FILE IS WANTED, TYPE "NL:" IN RESPONSE TO THE FOLLOWING:')
CALL ASSIGN(3,FNAME,ISREAD('PRINT FILE NAME',FNAME,3,30))
IF (.NOT.NEW) GO TO 30
N=ISREAD('JOB TITLE',JOBIII,1,60)
C
C      GET INFO FROM USER ON NEW FILE
C
0027      CALL DISPLAY
1('PROGRAM ALLOWS TWO LOAD CHANNELS')
0028      CALL DISPLAY
2('PLEASE CHARACTERIZE EACH LOAD CHANNEL')
0029      CALL DISPLAY
3('E.G. AXIAL OR PRESSURE OR UNUSED')
N=ISREAD('NAME OF LOAD TYPE 1',TLD(1,1),1,10)
N=ISREAD('NAME OF LOAD TYPE 2',TLD(1,2),1,10)
0030      CALL DISPLAY
0031      CALL DISPLAY
4('THE PROGRAM ALSO EXPECTS THREE STRAIN CHANNELS PER ROSETTE')
0032      CALL DISPLAY
5('PLEASE CHARACTERIZE THE TWO NORMAL STRAIN DIRECTIONS')
0033      CALL DISPLAY
6('E.G. AXIAL OR HUOP OR TRANSVERSE')
N=ISREAD('NAME OF STRAIN DIRECTION 1',TDIR(1,1),1,10)
N=ISREAD('NAME OF STRAIN DIRECTION 2',TDIR(1,2),1,10)
0034      ENCODE(10,5,TDIR(1,3))
0035      FORMAT(10H45 DEGREE )
0036      CALL PAUSE
0037      5
0038      C
0039      C

```



FURTHAN IV V02.04 FRI 04-JAN-80 09:46:52 PAGE 002  
 CONE=31K, UIC=(212,1) ,STRAIN/EX=STRAIN

```

C      READ IN RAW DATA
C
0040  DO 10 NRUN=1,1000
0041  IF (RANDAT(NRUN).LT.0.0) GO TO 20
0043  CONTINUE
0044  NRUN=NRUN+1
0045  WRITE(2) NRUN, TLD, TDIR, JUB11T
0046  CALL CLOSE(1)
0047  GO TO 40
0048  CALL GETDAT(0)
0049  CALL GETDAT(-1)
0050  CALL REVIEW

C      KEEP PLOTTING TILL USER WEARS OUT
C
0051  CALL PLTGEN
0052  REPEAT=.TRUE.
0053  CALL PLOT11
0054  IF (WANT('WANT TO FIT A CURVE')) CALL CURFIT
0055  IF (.NOT.WANT('WANT TO THROW OUT WILD POINTS')) GO TO 60
0056  CALL WILD
0057  GO TO 50
0058  GO TO 50
0059  IF (WANT('WANT ANY MORE PLOTS')) GO TO 40
0060  CALL DISPLAY('REMINDER: IF YOU GENERATED A PRINT FILE,')
0061  CALL DISPLAY(' PLEASE EITHER DELETE IT:')
0062  CALL DISPLAY(' >PIP FILENAME?#/DE')
0063  CALL DISPLAY(' OR SPOOL 11:')
0064  CALL DISPLAY(' >PIP FILENAME/SP1)
0065  CALL CLOSE(2)
0066  STOP
0067  END
0068
0069

```

```

FORTMAN IV      V02.04      PAGE 001
CORE=31K, UIC=(212,1)      ,RANDAT/EX=KANDAT

0001  C      FUNCTION RANDAT(NRUN)
      C      ROUTINE READS RAW DATA FILE AS OUTPUT BY SUN SYSTEM
      C      INTERPRETS AND STORES DATA FOR SUBSEQUENT PLOTTING

0002  C      COMMON/BINARY/
      C      1 NACT,
      C      2 NROS,
      C      3 MSHORT,
      C      4 PLUNG,
      C      5 LCH(2),
      C      6 ICHN(3,10),
      C      7 TITLE(60,4),
      C      8 NRD(30),
      C      9 IROS(30)
      C      1 NO. OF ACTIVE CHANNELS
      C      2 NO. OF ACTIVE ROSETTES
      C      3 LENGTH OF THE SHORTEST RECORD
      C      4 LENGTH OF THE LONGEST RECORD
      C      5 CHANNEL NO. FOR LOAD TYPE 1 & 2
      C      6 CHANNEL NO. FOR STRAIN TYPE 1, ROSETTE J
      C      7 TITLE INFO FROM RAW DATA FILE
      C      8 NO. OF HEADINGS ON CHANNEL 1
      C      9 ROSETTE NO. FOR CHANNEL 1 (OK LOAD IF < 0)

0003  C      COMMON/BINARY/
      C      1 ITYPE(30),
      C      2 A(30),B(30),
      C      3 TIME(80,30),
      C      4 VALUE(80,30)
      C      5 BYTE TITLE
      C      6 BYTE STUFF(19932)
      C      7 EQUIVALENCE (STUFF,NACT)
      C      8 COMMON/MISC/NRUN,ILD(10,2),TD1R(10,3),JOBTT(60)
      C      9 BYTE TLD,TDIN,JOBTT
      C      10 LOGICAL WANT,CHECK
      C      11 COMMON/PLT/NP(30),LYNE(126),LYNE2(126),LYNE3(126)
      C      12 BYTE LYNE,LYNE2,LYNE3
      C      13 BYTE BLANK,DOLLAR,X,E,O,R,LINE(20)
      C      14 DATA BLANK,DOLLAR,E,O,R/' ',' ','L','O','R'/'
      C      15 DATA LSTUFF/19932/
      C      16 DATA LVMAX/2040/
      C      17 CALL ERASE
      C      18 CALL BLANKIT(TITLE,4*60)
      C      19 NIT=2
      C      20 READ(1,22,END=30) (TITLE(J,1),J=1,60)
      C      21 TYPE 1,NRUN
      C      22 FORMAT (' READING RAW DATA FOR RUN NUMBER',J3/
      C      23 1 ' TITLE LINES READ FROM FILE:')
      C      24 AD=0.
      C      25 BD=0.
      C      26 CALL CLEAR(NRD,30)
      C      27 CALL CLEAR(IROS,30)
      C      28 CALL CLEAR(ITYPE,30)
      C      29 CALL CLEAR(ICHN,30)
      C      30 CALL CLEAR(LCH,2)
      C      31 WRITE(5,41) (TITLE(J,1),J=1,60)

      C      GET TITLE LINES
      C      32 READ(1,22,END=31) (TITLE(J,NIT),J=1,60)
      C      33 FORMAT (60A1)
      C      34 FOUND $, END OF TITLE INFO

```

FRI 04-JAN-80 09147106

PORTMAN IV V02.04  
CURE=31K, UIC=(212,1)

```

0032 IF (TITLE(1,NTIT),NE,DOLLAR) GO TO 40
0034 TITLE(1,NTIT)=BLANK
0035 NTIT=NTIT-1
0036 GO TO 50
C
C HIT ECP
C
0037 HANDAT=1.
0038 RETURN
0039 CALL DISPLAY(' EUR MISSING UN LAST RUN')
0040 HANDAT=1.
0041 RETURN
0042 CALL DISPLAY('EUR MISSING UN LAST RUN')
0043 CALL DISPLAY('YOU ARE FORGIVEN')
0044 GO TO 200
C
C GET ANOTHER LINE
C
0045 WRITE(5,41) (TITLE(J,NTIT),J=1,60)
0046 NTIT=NTIT+1
0047 WRITE(5,41) (TITLE(J,NTIT),J=1,60)
0048 FORMAT (1X,60A1)
0049 IF (NTIT.LE.4) GO TO 20
0051 READ(1,22) X
0052 NTIT=NTIT+1
0053 IF (X.EQ.DOLLAR) GO TO 50
0055 IF (NTIT.GT.10) STOP 'S MISSING AFTER TITLE LINES'
0057 GO TO 45
C
C READ IN RAW DATA AND CHECK FORMAT
C
0058 READ(1,51,END=32) NL,LINE
0059 FORMAT (0,20A1)
0060 IF (LINE(1),NE,E) GO TO 100
0062 IF (LINE(2),NE,O) GO TO 100
0064 IF (LINE(3),NE,R) GO TO 100
C
C END OF RECORD, GO PROCESS IT
C
0066 GO TO 200
C
C CHECK DATA FORMAT
C
0067 IF (CHECK(LINE,NL)) GO TO 100
0069 WRITE(5,60) (LINE(1),I=1,NL)
0070 FORMAT (' FOLLOWING LINE HAS A FORMAT ERROR:','1X,20A1)
0071 IF (.NOT.WANT('WANT TO DISCARD THIS LINE AND CONTINUE'))
1 STOP
GO TO 50
C
0073 DECODE CHANNEL NO., TIME, VALUE
C
0074 DECODE(20,110,LINE) JCHN,IMIN,ISEC,IFRAC,IVALLE

```

```

FURTHER IV      V02.04      FRI 04-JAN-80 09147100      PAGE 003
CONLSIN, UIC=(212,1)      ,HANDAT/EX=RAMDAT

0075 110      FORMAT (1X,13,1X,3(12,1X),15)
0076      IF (JCHN.LE.0.OR.JCHN.GT.30) GO TO 55
C
C      CHECK FOR OVERLOAD
C
0078      IF (IABS(IVALUE)-LE.IVMAX) GO TO 130
0080      WRITE(5,120) JCHN
0081 120      FORMAT (' OVERLOAD ON CHANNEL',13)
0082      GO TO 50
0083 130      NRDI(JCHN)=NRDI(JCHN)+1
0084      NRHDI(JCHN)
0085      IF (ISEC.GT.59) GO TO 55
0086      TIME(NR,JCHN)=60.*IMIN+ISEC+.01*IFHAC
      VALUE(NR,JCHN)=IVALUE
C
C      GO GET ANOTHER LINE
C
0089      GO TO 50
C
C      DONE READING, NOW HAVE TO RUN THRU EACH CHANNEL
C      AND GET MORE INFO FROM USER
C
0090 200      MSHORT=30000
0091      MLUNG=0
0092      DO 400 JCHN=1,30
0093      NRNRDI(JCHN)
0094      IF (NR.EQ.0) GO TO 400
0096      MSHORT=MIN0(MSHORT,NR)
0097      MLONG=MAX0(MLONG,NR)
0098      WRITE(5,210) JCHN
0099 210      FORMAT (' PLEASE IDENTIFY CHANNEL',13)
0100      N=ISREAD('S' FOR STRAIN; 'L' FOR LOAD; 'X' IF UNUSED',X,1,1)
C
C      STRAIN CHANNEL
C
0101      IF (X.NE.'S') GO TO 250
0103      JROS=IREAD('ROSETTE NO.',1,12,'NONE')
0104      WRITE(5,220) IDIR
0105 220      FORMAT (' STRAIN TYPES',/
1      1 12,10A1/
2      2 12,10A1/
3      3 12,10A1/
)
0106      JTYPE=IREAD('STRAIN TYPE FOR THIS CHANNEL',1,3,'NONE')
0107      IF (ICHN(JTYPE,JROS).EQ.0) GO TO 240
0109      WRITE(5,230) ICHN(JTYPE,JROS),JROS,(IDIR(J,JTYPE),J=1,10)
0110 230      FORMAT (' CHANNEL',13, HAS BEEN IDENTIFIED WITH ROSETTE',13,
12X,10A1, STRAIN')
C
0111      GO TO 205
0112 240      ITYPE(JCHN)=JTYPE
0113      IROS(JCHN)=JROS
0114      ICHN(JTYPE,JROS)=JCHN
0115      CALL DISPLAY('ENTER FACTORS A AND B TO CONVERT TO STRAIN UNITS')
0116      CALL DISPLAY(' WHERE N=RAW DATA, X=STRAIN UNITS')
0117

```

FORTHAN IV VO2.04 FM1 04-JAN-80 09147106 PAGE 004  
CORE=31K, UIC=(212,1) ,HANDAT/EXEHANDAT

```

0118 A(JCHN)=RREAD('A','NONE','NONE',AD)
0119 AD=A(JCHN)
0120 B(JCHN)=RREAD('B','NONE','NONE',BD)
0121 BD=B(JCHN)
0122 GO TO 400
C
C LOAD CHANNEL
C
0123 IF (X.NE.'L') GO TO 300
0125 WRITE(5,260) TLD
0126 FORMAT (' LOAD TYPES: ',
1 ' 1=1,10A1/
2 ' 2=1,10A1)
C
0127 ILD=IREAD('LOAD TYPE FOR THIS CHANNEL',1,2,'NONE')
0128 IF (LCH(ILD).EQ.0) GO TO 270
0130 WRITE(5,265) LCH(ILD),(TLD(J,ILD),J=1,10)
0131 FORMAT (' CHANNEL',13,' HAS BEEN IDENTIFIED WITH ',10A1,' LOAD',1)
0132 GO TO 205
0133 IROS(JCHN)=ILD
0134 LCH(ILD)=JCHN
0135 CALL DISPLAY('ENTER FACTORS A & B TO CONVERT TO LOAD UNITS')
0136 CALL DISPLAY(' X=AR+B')
0137 CALL DISPLAY(' WHERE K=RAW DATA, X=LOAD UNITS')
0138 A(JCHN)=RREAD('A','NONE','NONE',AD)
0139 AD=A(JCHN)
0140 B(JCHN)=RREAD('B','NONE','NONE',BD)
0141 BD=B(JCHN)
0142 GO TO 400
C
C UNUSED CHANNEL
C
0143 IF (X.NE.'X') GO TO 205
C
C NEXT CHANNEL
C
0145 CONTINUE
C
C THAT'S ALL! DUMP IT OUT
C
0146 WRITE(2) STUFF
0147 HANDAT=1.
C
C PRINT STUFF OUT
C
0148 IF (.NOT.WANT('WANT TO PRINT OUT RAW DATA')) GO TO 800
0150 WRITE(3,505) TITLE
0151 FORMAT (1H1/(1X,60A1))
0152 DO 508 I=1,30
0153 NP(I)=NRD(1)
0154 CALL BLANK1(LYNE,126*3)
0155 WRITE(3,511) LYNE
0156 FORMAT (1X,126A1)
0157 LTAB=0
0158 DO 610 I=1,30

```

```

0159 IF (NP(1).EQ.0) GO TO 610
0161 ENCODE(21,530,LYNE(21*LTAB+1)) 1
0162 530 FORMAT (6X,7HCHANNEL,13,5X)
0163 IF (IROS(1)) 580,580,535
0164 ENCODE(21,540,LYNE2(21*LTAB+1)) IROS(1)
0165 540 FORMAT (6X,7HROSETTE,13,5X)
0166 ENCODE(21,550,LYNE3(21*LTAB+1)) (TDIH(J,ITYPE(1)),J=1,10)
0167 550 FORMAT (2X,10A1,7H STRAIN,2X)
0168 GO TO 600
0169 ENCODE(21,570,LYNE2(21*LTAB+1))
0170 570 FORMAT (6X,6HUNUSED,7X)
0171 575 CALL BLANKIT(LYNE3(21*LTAB+1),21)
0172 GO TO 600
0173 ENCODE(21,590,LYNE2(21*LTAB+1)) (TLD(J,-IROS(1)),J=1,10)
0174 590 FORMAT (3X,10A1,5H LOAD,3X)
0175 CALL BLANKIT(LYNE3(21*LTAB+1),21)
0176 GO TO 575
0177 600 LTAB=LTAB+1
0178 IF (LTAB.EQ.6) GO TO 620
0179 CONTINUE
0180 610 IF (LTAB.EQ.0) GO TO 800
0181 620 WRITE(3,511) LYNE,LYNE2,LYNE3
0183 DU 625 ITAB=1,LTAB
0184 ENCODE(21,625,LYNE(21*(ITAB-1)+1))
0185 625 WRITE(3,511) LYNE
0186 626 FORMAT (4X,4HTIME,1X,7HREADING,5X)
0187 630 LTAB=0
0188 630 DO 680 I=1,30
0189 IF (NP(1)) 670,680,640
0190 N=NRD(1)-NP(1)+1
0191 640 IF (N.EQ.0) GO TO 670
0192 ENCODE(21,660,LYNE(21*LTAB+1)) TIME(N,1),VALUE(N,1)
0194 650 FORMAT (F8.2,F8.0,5X)
0195 660 NP(1)=NP(1)-1
0196 IF (NP(1).EQ.0) NP(1)=1
0197 GO TO 675
0199 CALL BLANKIT(LYNE(21*LTAB+1),21)
0200 670 LTAB=LTAB+1
0201 675 IF (LTAB.EQ.6) GO TO 685
0202 CONTINUE
0204 680 WRITE(3,511) LYNE
0205 685 DU 690 I=1,126
0206 IF (LYNE(1).NE.' ') GO TO 630
0207 CONTINUE
0209 L=0
0210 DO 700 I=1,30
0211 IF (NP(1).EQ.-1) NP(1)=0
0212 L=L+NP(1)
0214 700 CONTINUE
0215 IF (L.NE.0) GO TO 510
0216 CALL PAUSE
0218 800 RETURN
0219 END
0220

```

PK1 00-JAN-80 09:47:35

FORTHAN IV V02.04  
CURE=31K, UIC=(212,1)

```

0001 LOGICAL FUNCTION CHECK(LINE,N)
0002   BYTE LINE(20)
0003   LOGICAL NUM
0004   BYTE SHOULD(13),CHAR,ZERO,NINE
0005   DATA SHOULD/2,3,4,5,7,9,10,12,13,15,17,18,19/
0006   DATA ZERO,NINE/0,1,9/
0007   NUM(CHAR)=CHAR.GE.ZERO.AND.CHAR.LE.NINE
0008   CHECKEN.GE.19
0009   DO 10 I=1,13
0010     CHECK=CHECK.AND.NUM(LINE(SHOULD(I)))
0011   RETURN
0012   END

```

FORTRAN IV V02.04 PAGE 001  
CORE=3IN, UIC=(212,1) FRI 04-JAN-80 09:47:24 ,REVIEW/EX=REVIEW

```

0001 SUBROUTINE REVIEW
0002 COMMUN/MISC/NNUN,TLD(10,2),TDIR(10,3),JOUT11(60)
0003 BYTE TLD,TDIR,JOUT11
0004 COMMUN/BINARY/NACT,NROS,MSHURT,MLUNG,
1 LCH(2),ICHN(3,10),TITLE(60,4),NRD(30),INCS(30),
2 ITYPE(30),A(30),B(30),
3 TIME(80,30),VALUE(80,30)
0005 BYTE TITLE
0006 LOGICAL WANT
0007 DATA VMAX/2040, /
0008 IF (.NOT.WANT('WANT TO REVIEW RUNS ON FILE')) RETURN
0009 CALL ERASE
0010 DO 100 IRUN=1,NNUN
0011 CALL GETDAT(IRUN)
0012 WRITE(5,10) IRUN,TITLE
0013 FORMAT (' RUN',13/(4X,60A1))
0014 10 DO 50 ICH=1,30
0015 N=NRD(ICH)
0016 IF (N.EQ.0) GO TO 50
0017 DO 12 J=1,NR
0018 IF (ABS(VALUE(J,ICH)).GT.VMAX) GO TO 15
0019 12 CONTINUE
0020 J=NR
0021 NRD(ICH)=J
0022 15 IF (INCS(ICH)) 40,50,20
0023 WRITE(5,30) A(ICH),B(ICH),ICH,INCS(ICH),(TDIR(J,ITYPE(ICH)),J=1,10)
0024 20 FORMAT ('50','A',E10.4,5X,'B',E10.4,71,' CHANNEL',13,'1',
0025 1 ' ROSETTE NO.',13,2X,10A1)
0026 GO TO 50
0027 40 WRITE(5,45) A(ICH),B(ICH),ICH,(TLD(J,-INCS(ICH)),J=1,10)
0028 45 FORMAT ('50','A',E10.4,5X,'B',E10.4,11,' CHANNEL',13,'1',
0029 1 ' ,10A1,' LOAD')
0030 50 CONTINUE
0031 CALL PAUSE
0032 RETURN
0033 END
0034

```



FUKTRAN IV V02.04 FRI 04-JAN-80 09:47:47 PAGE 001  
 COMESIK, UIC=(212,1) ,GETDAT/EX=GETDAT

```

0001 SUBROUTINE GETDAT(IR)
      C
      C HEADS IN DATA FOR ONE RUN INTO COMMON BLOCK "BINARY"
      C EXCEPT IF IRUN=0, READS INTO BLOCK "MISC" FROM LAST REC
      C
      COMMON/MISC/NRUN, TLD(10,2), TDIR(10,3), JUBTIT(60)
      BYTE TLD, TDIR, JUBTIT
      COMMON/BINARY/STUFF(19932)
      BYTE STUFF
      DATA IPUS/-10/
      IRUN=IAHS(IR)
      IF (IRUN.NE.0) GO TO 30
      READ(2,END=20)
      GO TO 10
      BACKSPACE 2
      READ(2) NRUN, TLD, TDIR, JUBTIT
      REWIND 2
      IPUS=1
      RETURN
      IF (IRUN.LT.0.OR.IRUN.GT.NRUN)
      1 STOP 'BAD CALL TO GETDAT'
      IF (IPUS.EQ.-10) GO TO 80
      IF (IPUS.EQ.IRUN+1.AND.IR.GT.0) RETURN
      IF (IR.EQ.1.AND.NRUN.EQ.1) RETURN
      IF (IPUS=IRUN) 40,70,80
      NSKIP=IRUN-IPUS
      DO 60 I=1,NSKIP
      20 READ(2)
      60 READ(2) STUFF
      IPUS=IRUN+1
      IF (IRUN.LT.NRUN) RETURN
      30 REWIND 2
      IPUS=1
      RETURN
      REWIND 2
      80 IPUS=1
      NSKIP=IRUN-1
      IF (NSKIP.GT.0) GO TO 50
      GO TO 70
      END
  
```

FURTHAN IV V02.04 FRI 04-JAN-80 09:47:57 PAGE 001  
CORE=31K, UIC=(212,1) ,BLANKIT/EX=BLANKIT

0001 SUBROUTINE BLANKIT(LINE,N)  
0002 BYTE LINE(1)  
0003 DO 1 I=1,N  
0004 LINE(I)=','  
0005 RETURN  
0006 END



```

FORTMAN JV          V02.04          PRI 04-JAN-80 09:00:10          PAGE 002
CONE=31K, UIC=(212,1)          ,PLIGEN/EX=PLIGEN

0031      IF (TYPE.NE.'S') GO TO 35
C
C      PLUT A STRAIN
C
0033      IF (WANT('WANT TO PLOT A PRINCIPAL STRAIN')) GO TO 30
C
C      NOT A PRINCIPAL STRAIN
C
0035      WRITE(5,20) TDIR
0036      FORMAT(' STRAIN TYPES: ',
1      ' 1=,10A1/
2      ' 2=,10A1/
3      ' 3=,10A1)
JPLT(JAX)=IREAD('STRAIN KEY',1,3,'NONE')
GO TO 90

0037      PRINCIPAL STRAIN
0038      C
C
C
0039      CALL DISPLAY('PRINCIPAL STRAIN KEY:')
0040      CALL DISPLAY(' 1=MAJOR PRINCIPAL')
0041      CALL DISPLAY(' 2=MINOR PRINCIPAL')
0042      CALL DISPLAY(' 3=MAX SHEAR')
0043      JPLT(JAX)=3+IREAD('PRINCIPAL STRAIN KEY',1,3,'NONE')
0044      GO TO 90
C
C
C      PLUT A STRESS
C
0045      IF (TYPE.NE.'T') GO TO 12
0047      WRITE(5,40) ((TDIR(J,1),J=1,10),TLD,JJ=1,2)
0048      FORMAT(' ENTER FACTORS A & B REQUIRED TO CALCULATE ',10A1,
1      ' STRESS',1 FROM ',10A1,' AND ',10A1,' LOADS',
2      ' WHERE:',
3      ' S=A*L1 + B*L2',
4      ' S=,10A1,' STRESS',
5      ' L1=,10A1,' LOAD',
6      ' L2=,10A1,' LOAD')
SL(1,JAX,1)=READ('A','NONE','NONE','NONE',SL(1,JAX,1))
SL(1,JAX,2)=READ('B','NONE','NONE','NONE',SL(1,JAX,2))
WRITE(5,40) ((TDIR(J,2),J=1,10),TL2)
SL(2,JAX,1)=READ('A','NONE','NONE','NONE',SL(2,JAX,1))
SL(2,JAX,2)=READ('B','NONE','NONE','NONE',SL(2,JAX,2))
WRITE(5,40) (SHEAR,TLD,JJ=1,2)
SL(3,JAX,1)=READ('A','NONE','NONE','NONE',SL(3,JAX,1))
SL(3,JAX,2)=READ('B','NONE','NONE','NONE',SL(3,JAX,2))
IF (WANT('WANT A PRINCIPAL STRESS')) GO TO 60
C
C      NOT PRINCIPAL STRESS
C
0059      WRITE(5,50) ((TDIR(J,K),J=1,10),K=1,2),SHEAR
0060      FORMAT(' STRESS KEY:',
1      ' 1=,10A1/
2      ' 2=,10A1/
3      ' 3=,10A1)
JPLT(JAX)=IREAD('STRESS KEY',1,3,'NONE')
0061

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FORTMAN IV          V02.04          FRI 04-JAN-80 09:48:10          PAGE 003
CUMLE=31A, UIC=(212,1)          ,PLTGEN/EXEMPLIGEN

0062      GO TO 90
C
C      PRINCIPAL STRESS
C
0063      CALL DISPLAY('PRINCIPAL STRESS KEY:')
0064      CALL DISPLAY(' 1=MAJOR PRINCIPAL')
0065      CALL DISPLAY(' 2=MINOR PRINCIPAL')
0066      CALL DISPLAY(' 3=MAX SHEAR')
0067      JPLI(JAX)=3-IREAD('PRINCIPAL STRESS KEY',1,3,'NONE')

C      GET LABEL FOR THIS AXIS
C
0068      CALL BLANKIT(LABEL(1,JAX),40)
0069      LAB(JAX)=ISHEAD('LABEL FOR THIS AXIS',LABEL(1,JAX),1,40)

C      REPEAT FOR Y AXIS
C
0070      AX='Y'
C
C      GET TITLE FOR THE WHOLE PLOT
C
0071      CALL BLANKIT(PLTIT,60)
C
0072      NPIT=ISHEAD('TITLE FOR THE WHOLE PLOT',PLTIT,1,60)

C      ASK WHAT DATA TO PLOT
C
0073      CALL DISPLAY('YOU MAY NOW SPECIFY UP TO 8 CURVES')
0074      CALL DISPLAY(' TO BE DRAWN ON ONE PLOT')
0075      CALL REVIEW
0076      IRUN=1
0077      XMAX=0.
0078      XMIN=1.E6
0079      YMAX=0.
0080      YMIN=1.E6
0081      DO 600 I=1,8
0082      WRITE(5,110) ABC(CURVE)
0083      FORMAT (' FOR CURVE ',A1,1)
0084      IK=1
0085      IF (IRUN.GT.1) IR=IREAD('RUN NO.',1,IRUN,IRUN)
0086      CALL GETDAT(IR)
0087      C
C      DU X-AXIS
C
0088      JPL=JPLI(1)
0089      IF (JPL.LE.0) GO TO 180
C
C      STRAIN PLOTTED: GET DATA
C
0091      JRUS=IREAD('ROSETTE NO. FOR X AXIS',1,8,'NONE')
0092      IF (JPL.GT.3) GO TO 180
C
C      NOT PRINCIPAL STRAIN
C
0094      ICH=ICHN(JPL,JROS)

```

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FORTKIAN IV      V02.04      FRI 04-JAN-80 09:48:16      PAGE 004
CURE=3JK, UIC=(212,1)      ,PLTGEN/EX=PLTGEN

0095      NM=NRD(ICH)
0096      IF (NR.GT.0) GO TO 140
0098      WRITE(5,130) (TDIK(J,JPL),J=1,10),JKUS,IRUN
0099      FORMAT (1X,10A1,' STRAIN NOT RECORDED FOR ROSETTE NO.',13,'', RUN NO.',13)
0100      GO TO 120
0101      DO 150 I=1,NK
0102      XY(I,1,ICURVE)=VALUE(I,ICH)*A(ICH)+B(ICH)
0103      XY(I,1,ICURVE)=TIME(I,ICH)
0104      GO TO 300

C
C      PRINCIPAL STRAIN
C
0105      DO 170 J=1,3
0106      JCH(J)=ICHN(J,JKUS)
0107      IF (JCH(J).GT.0) GO TO 170
0109      WRITE(5,130) (TDIR(K,J),K=1,10),JKUS,IRUN
0110      GO TO 105
0111      CONTINUE
0112      NM=NRD(JCH(1))
0113      NXY(ICURVE)=NR
0114      DO 175 I=1,NK
0115      S(I)=VALUE(I,JCH(1))*A(JCH(1))+B(JCH(1))
0116      S(2)=XTEMP(VALUE(I,JCH(2)),TIME(I,JCH(2))),TIME(I,JCH(1)),NRD(JCH(2)))
0117      IF (S(2).EQ.OVER) GO TO 176
0118      S(3)=XTEMP(VALUE(I,JCH(3)),TIME(I,JCH(3)),TIME(I,JCH(1)),NRD(JCH(3)))
0119      IF (S(3).EQ.OVER) GO TO 176
0120      CALL PRINCIPAL(S,I,ANG)
0121      XY(I,1,ICURVE)=T(JPL-3)
0122      XY(I,1,ICURVE)=TIME(I,JCH(1))
0123      GO TO 300
0124      175
0125      NXY(ICURVE)=I-1
0126      GO TO 300
0127      C
C      STRESS ON X AXIS
C
0128      180
0129      JPL=JPL
0130      IF (JPL.GT.3) GO TO 220
C
C      NOT A PRINCIPAL STRESS
C
0131      LD=1
0132      IF (NRD(LCH(2)).GT.NRD(LCH(1))) LD=2
0133      DO 200 LD=1,2
0134      IF (SL(JPL,1,LD).EQ.0..OR.NRD(LCH(LD)).NE.0) GO TO 200
0135      WRITE(5,190) (TLD(J,LD),J=1,10),IRUN
0136      FORMAT (' NO DATA FOR ',10A1,' LOAD FOR RUN',12)
0137      GO TO 105
0138      190
0139      CONTINUE
0140      NM=NRD(LCH(LD))
0141      NXY(ICURVE)=NR
0142      LCH1=LCH(3-LD)
0143      LCH2=LCH(LD)
0144      DO 210 I=1,NK
0145      XLDI=A(LCH1)*VALUE(I,LCH1)+B(LCH1)
0146

```



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(
(
FORTTRAN 1V          V02.04          PAGE 000
CURE=31K, UIC=(212,1)          FRI 04-JAN-80 09140816          ,PLIGEN/LX=PLIGEN
(
(
0196          IF (X1.EQ.OVER) GO TO 351
0198          XY(1,2,ICURVE)=A(ICH)*X1+B(ICH)
0199          GO TO 500
0200          NXY(ICURVE)=1-1
0201          GO TO 500
(
C
C
C          PRINCIPAL STRAIN
C
C
0202          DO 370 J=1,3
0203          JCH(J)=ICHN(J,JKUS)
0204          IF (JCH(J).GT.0) GO TO 370
0206          WRITE(5,130) (TOIK(K,J),K=1,10),JKUS,IRUN
0207          GO TO 105
0208          CONTINUE
0209          NK=NXY(ICURVE)
0210          DO 375 I=1,NK
0211          DO 372 J=1,3
0212          S(J)=XTEMP(VALUE(1,JCH(J)),TIME(1,JCH(J)),XYT(1,ICURVE),NRD(JCH(J)))
0213          IF (S(J).EQ.OVER) GO TO 376
0215          CONTINUE
0216          CALL PRINC(8,T,ANG)
0217          XY(1,2,ICURVE)=T(JPL=3)
0218          GO TO 500
0219          NXY(ICURVE)=1-1
0220          GO TO 500
(
C
C
C          STRESS ON Y AXIS
C
C
0221          JPL=JPL
0222          IF (JPL.GT.3) GO TO 430
(
C
C
C          NOT A PRINCIPAL STRESS
C
C
0224          DO 400 LLD=1,2
0225          IF (SL(JPL,2,LD),EQ.0.OR.NRD(LCH(LLD)),NE.0) GO TO 400
0227          WRITE(5,190) (TLD(J,LLD),J=1,10),IRUN
0228          GO TO 105
0229          CONTINUE
0230          NK=NXY(ICURVE)
0231          LCH1=LCH(1)
0232          LCH2=LCH(2)
0233          DO 410 I=1,NK
0234          XLD1=XTEMP(VALUE(1,LCH1),TIME(1,LCH1),XYT(1,ICURVE),NRD(LCH1))
0235          IF (XLD1.EQ.OVER) GO TO 411
0237          XLD1=A(LCH1)*XLD1+B(LCH1)
0238          XLD2=XTEMP(VALUE(1,LCH2),TIME(1,LCH2),XYT(1,ICURVE),NRD(LCH2))
0239          IF (XLD2.EQ.OVER) GO TO 411
0241          XY(1,2,ICURVE)=SL(JPL,2,1)*XLD1+SL(JPL,2,2)*XLD2
0242          GO TO 500
0243          NXY(ICURVE)=1-1
0244          GO TO 500
(
C
C
C          PRINCIPAL STRESS
C
C

```



```

FORTRAN IV      V02.04      FHI 04-JAN-80 09:48116      PAGE 007
CORE=31K, UIC=(212,1)      ,PL1GEN/EX=PL1GEN

0245 430 DO 440 LLD=1,2
0246 IF (NHD(LCH(LLD)),NE.0) GO TO 430
0248 WRITE(5,190) (ILD(J,LLD),J=1,10),IRUN
0249 GO TO 105
0250 440 CONTINUE
0251 N=NX(1,ICURVE)
0252 LCH1=LCH(1)
0253 LCH2=LCH(2)
0254 DO 460 I=1,NR
0255 XLD1=XTEKP(VALUE(1,LCH1),TIME(1,LCH1),XY(1,1,ICURVE),NHD(LCH1))
0256 IF (XLD1.EQ.OVER) GO TO 461
0258 XLD1=A(LCH1)*XLD1+B(LCH1)
0259 XLD2=XTEKP(VALUE(1,LCH2),TIME(1,LCH2),XY(1,1,ICURVE),NHD(LCH2))
0260 IF (XLD2.EQ.OVER) GO TO 461
0262 XLD2=A(LCH2)*XLD2+B(LCH2)
0263 DO 450 J=1,3
0264 S(J)=SL(J,2,5-LD)*XLD1+SL(J,2,LD)*XLD2
0265 CALL PRINC(S,1,ANG)
0266 XY(1,2,ICURVE)=T(JPL-3)
0267 GO TO 500
0268 461 NX(1,ICURVE)=I-1
0269 GO TO 500
0270 500 DO 510 I=1,NX(1,ICURVE)
0271 XMAX=MAX1(XMAX,XY(1,1,ICURVE))
0272 XMIN=MIN1(XMIN,XY(1,1,ICURVE))
0273 YMAX=MAX1(YMAX,XY(1,2,ICURVE))
0274 YMIN=MIN1(YMIN,XY(1,2,ICURVE))
0275 IF (NRUN.GT.1) WRITE(5,520) TITLE
0277 520 FORMAT (' TITLE INFO FROM SUN FILE:','(IX,60A1))
0278 CALL BLANKIT(LEGEND(1,ICURVE),40)
0279 NLEG=ISREAD('A SUMMARY TITLE FOR THIS CURVE',
1 LEGEND(1,ICURVE),1,40)
IF (.NOT.WANT('WANT ANY MORE CURVES ON THIS PLOT')) GO TO 700
CONTINUE
NCURVE=ICURVE
REPEAT=.TRUE.
RETURN
END
0280 600
0282 700
0283
0284
0285
0286

```

FHI 04-JAN-80 09:48:42

FURTRAN IV V02.04  
CURESSIN, UIC=(212,1)

```

0001 FUNCTION XTERP(VALUE,TIME,T,N)
0002 DIMENSION VALUE(1),TIME(1)
0003 DATA OVER/
0004 WRITE(3,76) (TIME(I),VALUE(I),I=1,N)
0005 FORMAT (F7.2,F8.2,2X)
0006 IF (1.GT.TIME(1)) GO TO 10
0007 XTERP=VALUE(1)
0008 GO TO 30
0009 DO 15 I=1,N
0010 IF (1.GE.TIME(I).AND.1.LT.TIME(I+1)) GO TO 20
0011 CONTINUE
0012 XTERP=OVER
0013 GO TO 30
0014 S=(VALUE(I+1)-VALUE(I))/(TIME(I+1)-TIME(I))
0015 XTERP=VALUE(I)+S*(1-TIME(I))
0016 CONTINUE
0017 WRITE(3,77) 1,XTERP
0018 FORMAT (' XTERP',F7.2,F10.2)
0019 RETURN
0020 END

```

FURTHAN IV VU2.04 FRI 04-JAN-80 09:48:58 PAGE 001  
 COME\*3IN, UIC=(212,1) ,SCALE/EXPSCALE )

```

0001 FUNCTION SCALE(X)
0002 DIMENSION XLIM(10)
0003 DATA XLIM/1.,1.25,1.5,2.0,2.5,3.0,4.0,5.0,7.5,10.0/
0004 SCALE=0.0
0005 IF(X.EQ.0.0) RETURN
0006 I=ALOG10(ABS(X))
0007 Y=ABS(X)*10.0**(-I)
0008 DO 10 J=1,10
0009 IF(Y.LE.XLIM(J)) GO 10 20
0010 CONTINUE
0011 STOP 'SCALE ERROR'
0012 10 SCALE=SIGN(XLIM(J)*10.0**I,X)
0013 20 RETURN
0014 END
0015
0016

```

```

0001 SURROUTINE PRINC(S,T,ANG)
0002 DIMENSION S(3),T(3)
      C
      S(1)=S(2)=NORMAL STRAINS
      S(3)=45 DEGREE STRAIN
      T(1),T(2)=PRINCIPAL STRAINS
      T(3)=MAX SHEAR
      C
      A=(S(1)+S(2))/2.
      B=((S(1)-S(2))*2+(S(3)-S(2))*2)/2.
      H=SQRT(B)
      SUM=A+B
      DIFF=A-B
      IF (ABS(DIFF).GT.ABS(SUM)) GO TO 10
      T(1)=SUM
      T(2)=DIFF
      GO TO 20
      T(1)=DIFF
      T(2)=SUM
      T(3)=ABS(T(1)-T(2))
      RETURN
      END
0003
0004
0005
0006
0007
0008
0010
0011
0012
0013 10
0014
0015 20
0016
0017

```

```

FURMAN IV          VU2.04          PAGE 001
CURVE3IN, UIC=(212,1)          ,CURFIT/EXECURFIT

0001  SUBROUTINE CURFIT
      C
      C  DRAW LEAST SQUARES CURVE FIT THRU DATA
      C  GENERATED BY PLTGEN AND PLOTTED
      C  INDIVIDUALLY BY PLU111
      C
      COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOB111(60)
      BYTE TLD,TDIR,JOB111
      COMMON/PL1/NCURVE,XMAX,XMIN,YMAX,YMIN,XSC,YSC,XL,YL,
1      XY(70,2,8),XY(70,8),NXY(8),
2      NLAB(2),LABEL(40,2),NP111,PLT11(60),
3      LEGEND(40,8)
      BYTE LABEL,PLT11,LEGEND
      COMMON/BINAKY/X(400),Y(400),Z(400)
      CALL PLOTS
      CALL PLOT(0,,0,-3)
      CALL PLOT(2,2,-3)
      CALL AXIS(0,,0,LABEL(1,1),NLAB(1),XL,0,0,ABS(XSC/XL))
      CALL AXIS(0,,0,LABEL(1,2),NLAB(2),YL,90,0,ABS(YSC/YL))
      CALL GRID(0,,0,16,10,0)
      CALL SYMBOL(10,,12.5,'LEGEND',,6)
      SYMB='A'
      DO 20 ICURVE=1,NCURVE
      CALL SG13(XY(1,2,ICURVE),XY(1,1,ICURVE),Z,NXY(ICURVE),IER)
      Z(NXY(ICURVE)+1)=0
      Z(NXY(ICURVE)+2)=ABS(XSC/XL)
      CALL LINE(Z,XY(1,2,ICURVE),NXY(ICURVE),1,1,ICURVE)
      CALL SYMBOL(10,,12.5-4*ICURVE,,SYMB,,1)
      CALL SYMBOL(10,5,12.5-4*ICURVE,,LEGEND(1,ICURVE),,40)
      SYMB=SYMB+1
20  CALL SYMBOL(0,,12.5,,JOB111,,60)
      CALL SYMBOL(0,,12.0,,PLT11,,NP111)
      CALL SYMBOL(0,,11.5,'LEAST SQUARES FIT',,17)
      CALL PLOT(,,999)
      RETURN
      END
0029

```



```

FORMTRAN IV          V02.04          PK1 04-JAN-80 09150101          PAGE 002
CURE=31K, UIC=(212,1)          ,PLOT11/EXPLOT11

0045      IC2=MIND(NCURVE,4)
0046      CALL BLANKIT(LYNE,2*128)
0047      WRITE(3,101) LYNE
0048      FORMAT (1X,128A1)
0049      JCURVE=ICURVE
0050      DO 130 I=1,IC2
0051      ICURVE=ICURVE+1
0052      WRITE(3,110) ABC(ICURVE),(LEGEND(J,ICURVE),J=1,40)
0053      FORMAT (1X,40A1,' ',40A1)
0054      ENCODE(30,120,LYNE(30*1-29)) ABC(ICURVE)
0055      FORMAT (11X,5MCURVE,1X,A1,11X)
0056      ENCODE(30,140,LYNE2(30*1-29))
0057      FORMAT (11X,1MX,11X,1MY,6X)
0058      WRITE(3,101)
0059      WRITE(3,101) LYNE,LYNE2
0060      DO 180 L=1,10000
0061      ICURVE=JCURVE
0062      DO 160 I=1,IC2
0063      CALL BLANKIT(LYNE(30*(I-1)+1),30)
0064      ICURVE=ICURVE+1
0065      IF (L.LE.NXY(ICURVE))
1          ENCODE(30,150,LYNE(30*1-29)) XY(L,1,ICURVE),XY(L,2,ICURVE)
0067      150      FORMAT (E15.5,E12.5,5X)
0068      CONTINUE
0069      WRITE(3,101) LYNE
0070      DO 170 I=1,128
0071      IF (LYNE(I).NE.' ') GO TO 180
0072      CONTINUE
0073      GO TO 190
0074      CONTINUE
0075      180      IC2=MIND(NCURVE-ICURVE,4)
0076      190      IF (ICURVE.EQ.1,NCURVE) GO TO 102
0077      C
0078      C
0079      C      HERE GOES
0080      C
0081      CALL DISPLAY('READY TO PLOT,')
0082      CALL PAUSE
0083      CALL PLOT(2,2,-3)
0084      CALL AXIS(0,0,0,LABEL(1,1),NLAB(1),XL,0,0,0,ABS(XSC/XL))
0085      CALL AXIS(0,0,0,LABEL(1,2),NLAB(2),YL,90,0,0,ABS(YSC/YL))
0086      CALL GRID(0,0,0,16,10,0,0)
0087      DO 710 ICURVE=1,NCURVE
0088      DO 500 J=1,NXY(ICURVE)
0089      IF (XL.EQ.0) XY(J,1,ICURVE)=XY(J,1,ICURVE)
0090      IF (YL.EQ.0) XY(J,2,ICURVE)=XY(J,2,ICURVE)
0091      XY(J,1,ICURVE)=AMAX1(0,XY(J,1,ICURVE))
0092      CONTINUE
0093      500      XY(NXY(ICURVE)+1,1,ICURVE)=0
0094      XY(NXY(ICURVE)+2,1,ICURVE)=ABS(XSC/XL)
0095      XY(NXY(ICURVE)+1,2,ICURVE)=0
0096      XY(NXY(ICURVE)+2,2,ICURVE)=ABS(YSC/YL)
0097      CALL LINE(XY(1,1,ICURVE),XY(1,2,ICURVE),NXY(ICURVE),1,1,ICURVE)
0098      CALL SYMBOL(0,12.5,7JUB111,60)
0099

```

FORTKAM IV V02.04 FRI 04-JAN-80 09:50:01 PAGE 003  
CORE=31K, UIC=(212,1) ,PL0111/EXPLO111

0100 CALL SYMBOL(0,,12.0,,PL111,,NPT11)  
0101 CALL SYMBOL(10,,12.5,,LEGEND',,0)  
0102 SYMB=1'  
0103 DO 810 ICURVE1,NCURVE  
0104 CALL SYMBOL(10,,12.5-.4\*ICURVE,,SYMB,,1)  
0105 SYMB=SYMB+1  
0106 810 CALL SYMBOL(10.5,12.5-.4\*ICURVE,,LEGEND(1,ICURVE),,40)  
0107 CALL PL01(,,999)  
0108 RETURN  
0109 END



SUBROUTINE SC13(X,Y,Z,NDIM,IER)

LEAST SQUARES ROUTINE

DIMENSION X(NDIM),Y(NDIM),Z(NDIM)

IF(NDIM=3,1,1)

DO 6 1=3,NDIM

XN=X(1-3)+X(1-2)+X(1-1)+X(1)

YN=X(1-3)+X(1-2)+X(1-1)+X(1)

Z=X(1-2)+XN

T2=X(1-1)+XN

T3=X(1)-XN

XN=X(1)+T2+T3+T3

IF(XN)3,3,2

XN=(T1+Y(1-2)-YN)+T2+Y(1-1)-YN)+T3+Y(1)-YN)/XN

IF(1-3)4,4,5

H=XN+T1+YN

Z(1-2)=H

H=XN+T2+YN

Z(NDIM-1)=H

Z(NDIM)=XN+T3+YN

IER=0

RETURN

IER=-1

RETURN

END



APPENDIX B

RING TESTER

### INTERNAL PRESSURE-ONLY COMPOSITE RING TEST FIXTURE

As part of Problem No. 112, an internal pressure-only tube test fixture was designed and built. The design of the fixture is essentially the same as that of a fixture successfully used by the IIT Research Institute under contract to AFFDL. Technical Report AFFDL-TR-75-11, titled "Analytical-Experimental Correlation of the Biaxial State of Stress in Composite Laminates (T-300/5208)," may be used as a reference.

Several uninstrumented  $0^\circ/\pm 45^\circ/90^\circ$  graphite epoxy rings have been successfully ruptured in the fixture. The results are disappointing, however, when specimens having high Poisson ratios, such as  $\pm 45^\circ$  layups, are pressurized. In those tests, the large Poisson contraction in the axial direction allows extrusion of the internal rubber gasket between the specimen end and pressure collet. This destroys the pressure seal and prevents further application of fluid pressure.

A drawing of the fixture showing an assembly view of the main body, lock rings and pressure collets, is given in Figure B.1. A photograph showing the entire assembled fixture is given in Figure B.2. A schematic of the fixture is given in Figure B.3. The maximum pressure of this system is 5,000 psi. The gage accuracy is  $\pm 2\%$  at full scale.

A pressure transducer must be installed in the pipe tee adjacent to the pressure gage. A Daytronic strain gage transducer, Model 502-3000G, has been used successfully with this fixture. If the data from the transducer is not required, a high pressure pipe plug ( $> 5,000$  psi.) may be installed in its place.

To begin operation, fill the reservoir with hydraulic fluid. Open valves designated as Nos. 1, 2, 3 and 4 in Figure B.3. Fill the open reservoir at the end of the priming pump  $3/4$  full with hydraulic fluid. Close the relief valve at the other end of the priming pump. Pump the lever on the

## HYDROSTATIC TEST FIXTURE

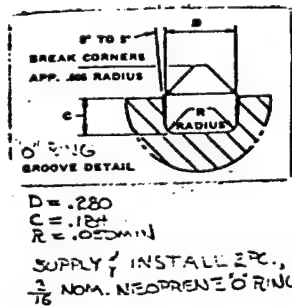


Figure B.1 Dimensioned Drawing of  
Internal Pressure Only  
Fixture

MATERIALS: BODY - STEEL  
LOCK NUTS - STEEL  
COLLETS - 4340,  $R_c - 45$

SCALE - FULL  
TOL.  $\pm 0.005$ , EXCEPT AS NOTED  
BREAK ALL CORNERS

N.L.H.  
9-8-78

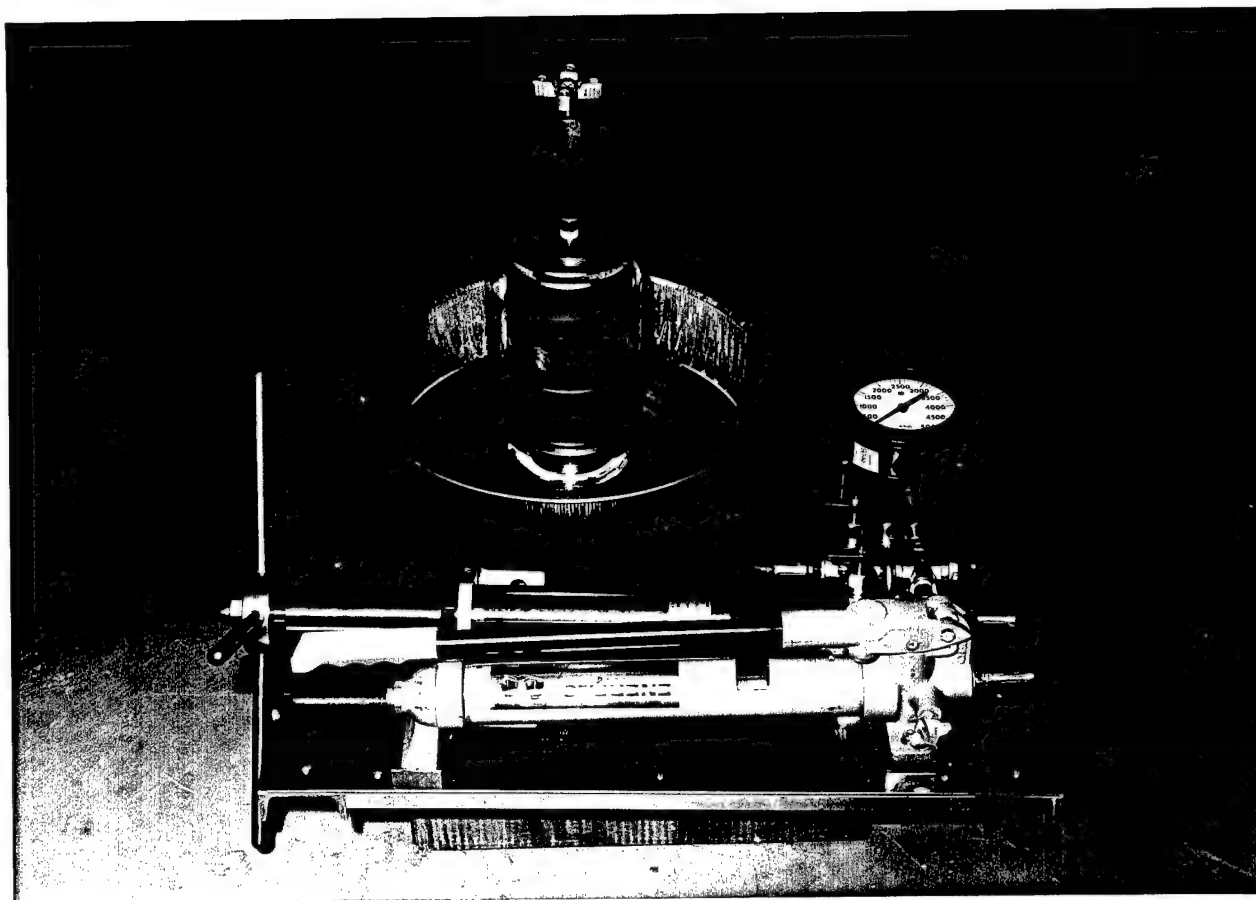


Figure B.2   Internal Pressure Only Test  
Fixture

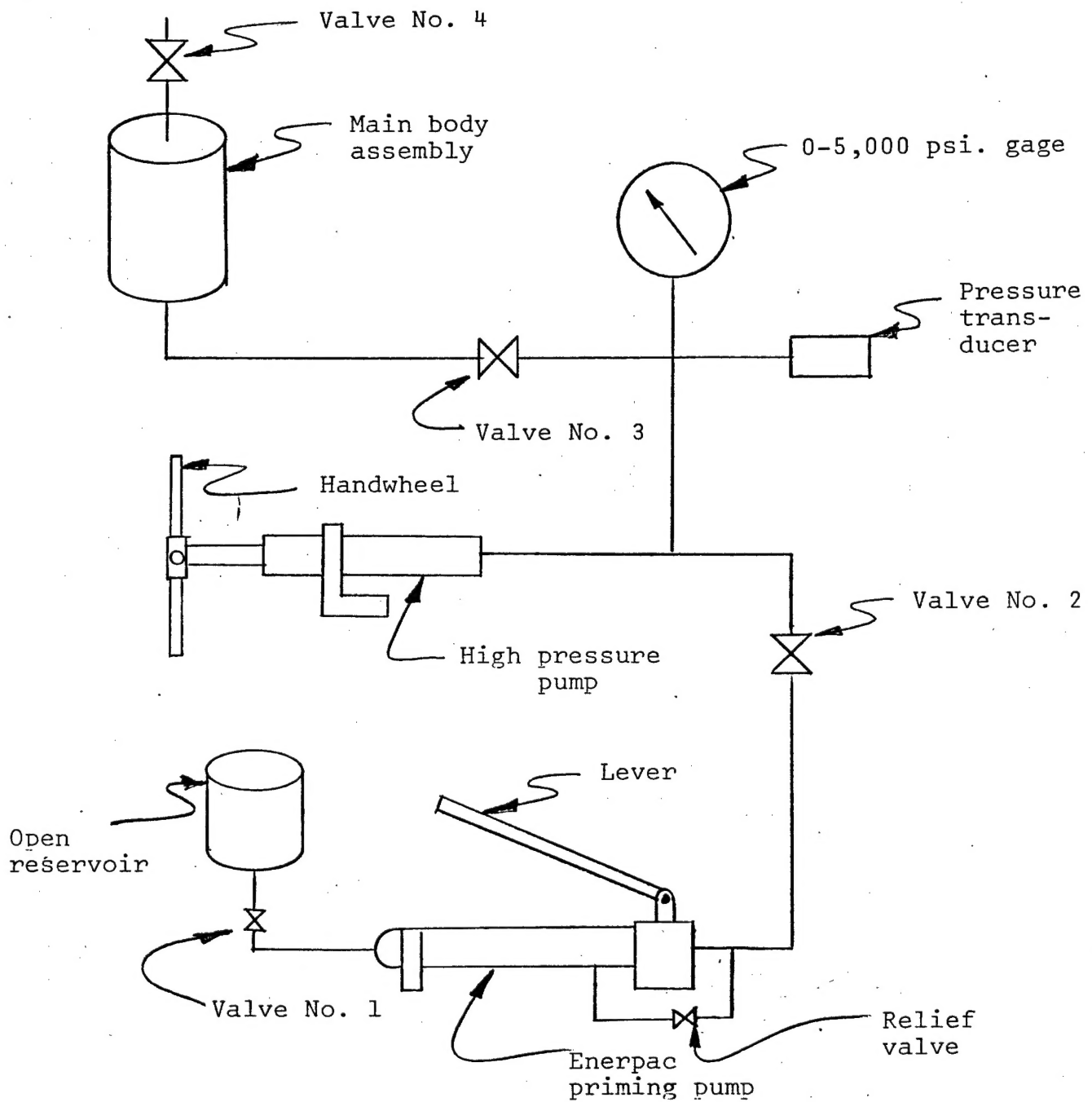


Figure B.3 Schematic of the Internal Pressure-only Composite Ring Test Fixture

priming pump until a steady flow of fluid leaks out of the main body, making sure that the open reservoir is never less than  $1/4$  full. Crank the handwheel on the high pressure pump clockwise until it stops. Close Valve No. 3. Slowly crank the handwheel counter-clockwise while pumping the lever on the priming pump. Keep a gage pressure of about 300 psi. Continue cranking until the shaft is fully extended. Open the relief valve on the priming pump to release the pressure.

To mount the test specimen, unscrew and remove the upper lock ring and upper pressure collet from the main body. Loosen the lower lock ring and screw the lower pressure collet down about 1.5 inches from its full up position. Cut a piece of the red rubber gasket tube about an inch longer than the specimen. This gasket tube is about  $3 \frac{5}{8}$ " diameter and 0.10 inches thick, and was supplied by the Air Force. Slide the tube around the outside diameter of the main body, down far enough that it is centered around the fluid/air holes. Screw the lower pressure collet up the main body so that it slides over the gasket tube as far as it will go. Lock the lower lock ring. Slide the instrumented specimen over the outside of the gasket tube so that it rests on the lower pressure collet. Screw the upper pressure collet down so that the bottom edge rests on the specimen. The upper pressure collet should slide over the gasket tube just as the lower collet did. The length of the gasket tube may have to be trimmed so that the upper collet will rest on the specimen. Screw down the upper lock ring to lock the pressure collet. A photograph of the specimen in place is shown in Figure B.4.

Now that the specimen has been mounted, set up all of the signal conditioning for the pressure transducer and the specimen strain gages. Open Valves No. 1, No. 2, No. 3 and No. 4. Close the relief valve on the priming pump. As much air as



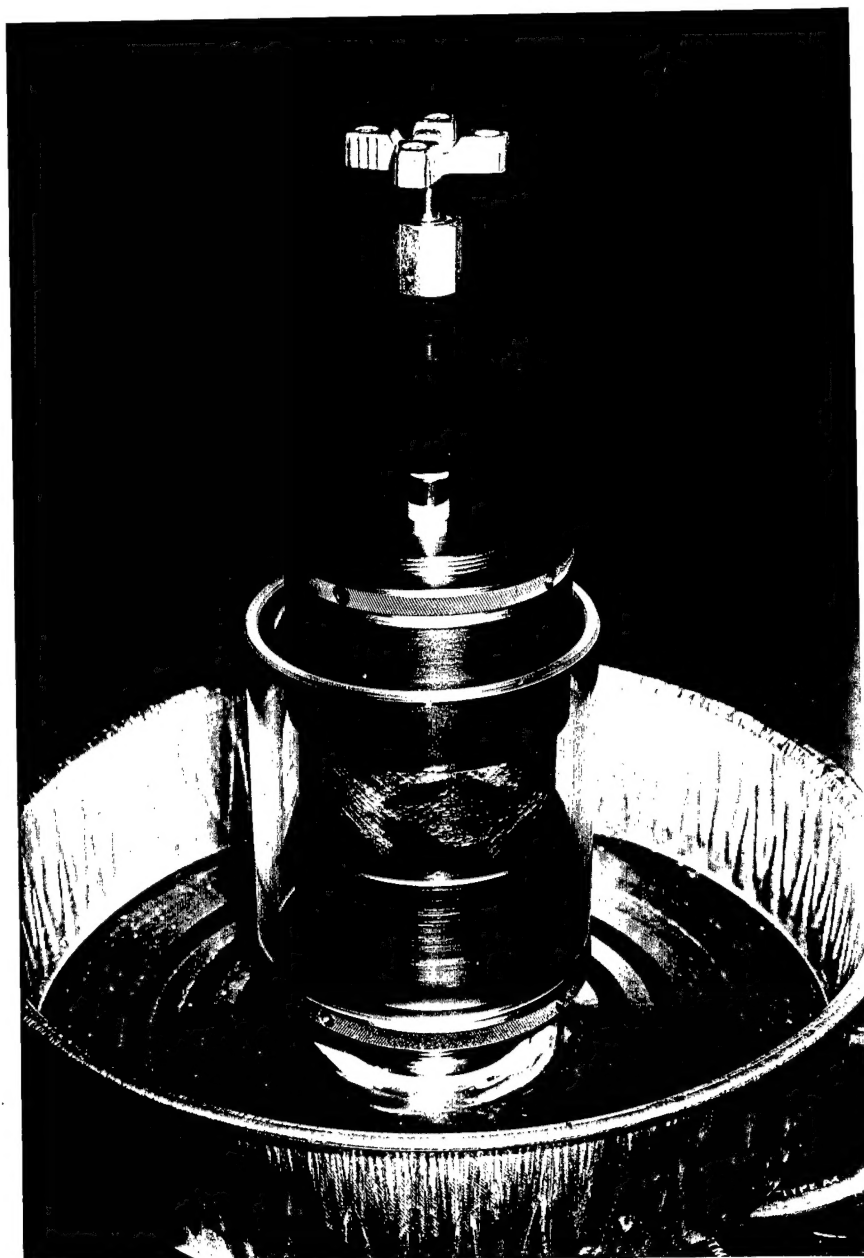


Figure B.4 Test Specimen Mounted in Fixture

possible must be gotten out of the system. This is done by pumping the priming pump until a steady flow of fluid comes out of Valve No. 4. The air that is trapped around the specimen will leave through the fluid/air holes in the main body.

After all the air is out, the pressure transducer can be calibrated against the pressure gage. Close Valves No. 2 and No. 3. By cranking the handwheel clockwise, a pressure will be produced at the pressure gage and transducer without applying pressure to the specimen. To release the pressure, crank the handwheel counter-clockwise until the shaft is fully extended, and open Valve No. 2 and the relief valve on the priming pump.

To test the specimen, close Valves No. 2 and No. 4. Open Valve No. 3. Place the plexiglass tube over the specimen so that it rests on the lower lock ring. Apply pressure to the specimen by cranking the handwheel clockwise. To release the pressure, open Valve No. 2 and the relief valve on the priming pump. After the specimen has ruptured, drain the fluid out of the drain pan by removing the pipe plug in the bottom of the pan.